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ABSTRACT

This manual provides guidance for putting into initial operation a new municipal wastewater treatment plant, a new addition to an existing treatment plant, or a change in the mode of a treatment plant's operation. Information is provided on preparing for actual treatment plant start-up. Preparation for start-up includes: staffing the plant, developing standard operating procedures, conducting dry- and wet-running testing of equipment, providing on-site operator training, conducting safety training, and establishing procedures when construction is continuing during start-up. This manual describes start-up procedures for some of the more common pretreatment and primary treatment units; for the specific secondary treatment processes of activated sludge, trickling filters, stabilization ponds, and aerated lagoons; and for sludge handling units and the anaerobic digestion process. The start-up procedures for advanced wastewater treatment units and processes are not within the scope of this manual. References are provided for additional information on administrative and process considerations; a glossary of pertinent wastewater terms is also included. (Author/BB)

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START-UP OF MUNICIPAL WASTEWATER TREATMENT FACILITIES

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ENGINEERS - ARCHITECTS - PLANNERS
LYNCHBURG, VIRGINIA

SE 024 119

MANUAL
OF
CONSIDERATIONS AND TECHNIQUES
FOR
START-UP
OF
MUNICIPAL WASTEWATER
TREATMENT FACILITIES

by

R. D. Rader
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WILEY & WILSON, INC.
ENGINEERS . ARCHITECTS . PLANNERS
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FOR THE
U. S. ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF WATER PROGRAMS OPERATIONS
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EPA Review Notice

This report has been reviewed by the Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

ABSTRACT

This manual provides guidance for putting into initial operation a new municipal wastewater treatment plant, a new addition to an existing treatment plant, or a change in the mode of a treatment plant's operation. Proper operation of the treatment plant or process will ensure that the wastewater is treated in compliance with the specific conditions and limitations established for each treatment facility.

Information is provided on preparing for actual treatment plant start-up. Preparation for start-up includes: staffing the plant, developing standard operating procedures, conducting dry- and wet-run testing of equipment, providing on-site operator training, conducting safety training, and establishing procedures when construction is continuing during start-up.

This manual describes start-up procedures for some of the more common pretreatment and primary treatment units; for the specific secondary treatment processes of activated sludge, trickling filters, stabilization ponds and aerated lagoons; and for sludge handling units and the anaerobic digestion process. The start-up procedures for advanced wastewater treatment units and processes are not within the scope of this manual.

References are provided for additional information on administrative and process considerations; a glossary of pertinent wastewater terms is also included.

This report was submitted in fulfillment of Contract Number 68-01-0341 under the sponsorship of the Municipal Operations Branch, Office of Water Programs Operations, U. S. Environmental Protection Agency.

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SECTION I
INTRODUCTION

The primary function of municipal wastewater treatment facilities is to collect and treat municipal wastewaters so as to attain the national ". . . goal of water quality which provides for the protection and propagation of fish, shellfish, and wildlife, and provides for recreation in and on the water." The Federal Water Pollution Control Act Amendments of 1972 stipulate that this function is to be accomplished by publicly owned treatment works in a consistent and reliable manner so as to meet effluent limitations based upon secondary treatment or any more stringent applicable limitations, by July 1, 1977, and so as to employ the best practicable waste treatment technology by July 1, 1983. The specific conditions and limitations will be identified in a permit issued to each point source discharge under the "National Pollutant Discharge Elimination System" established by the Act.

Since the discharge of pollutants in excess of the effluent limitations defined in the plant's discharge permit is prohibited by the Act, municipal wastewater treatment plants, from the day of initial operation, must begin to effectively increase the degree of treatment of the wastewater. This manual has been prepared to assist in the accomplishment of this objective.

Start-up can be defined as a series of events that lead to a stabilized, routinely controlled plant, process, or unit. The manual provides considerations on preparations prior to start-up, starting up the pretreatment, primary treatment and chlorination facilities, and techniques and considerations on starting up secondary treatment processes and sludge handling processes and units.

The manual is presented in four major sections. The first major section, Preparation for Start-Up, applies to all facilities regardless of type or size. It further applies whether starting up a completely new wastewater treatment plant or starting up a new process or unit that has been added to an existing wastewater treatment plant.

The following section, Start-Up of the Pretreatment, Primary Treatment, and Chlorination Facilities, gives considerations for starting up some of the more common physical and chemical units involved in wastewater treatment plants.

Section IV, Start-Up of the Secondary Facilities, gives considerations and techniques for starting up the biological processes based upon parameters involved in the design and recognized techniques used for start-up.

The fourth major section, Start-Up of the Sludge Handling Facilities, provides considerations for start-up of the more common sludge handling units and considerations and techniques for starting up an anaerobic digester based upon the design parameters and recognized techniques used for start-up.

The manual should be used by anyone involved with the start-up of a wastewater treatment plant, process, or unit. It is intended to be a useful source document for persons preparing start-up recommendations for the start-up section of the plant's Operation and Maintenance Manual. The manual is also intended to provide considerations and techniques for starting up a new plant, process, or unit, or restarting processes or units. Persons using the manual should exclude only the particular units or processes that the facility does not have; however, Section II, Preparation for Start-Up, is general and broad enough to provide information on starting up an entire facility or only a particular unit.

The manual further can be used as a general description or reference to plant operations and functions.

SECTION II
PREPARATION FOR START-UP

This section deals with considerations for the administrative and operational procedures that should be followed before start-up. Following this guidance will eliminate many problems and the potential for problems often associated with start-up. The considerations can be used equally as well by experienced or nonexperienced supervisors in their preparation for start-up.

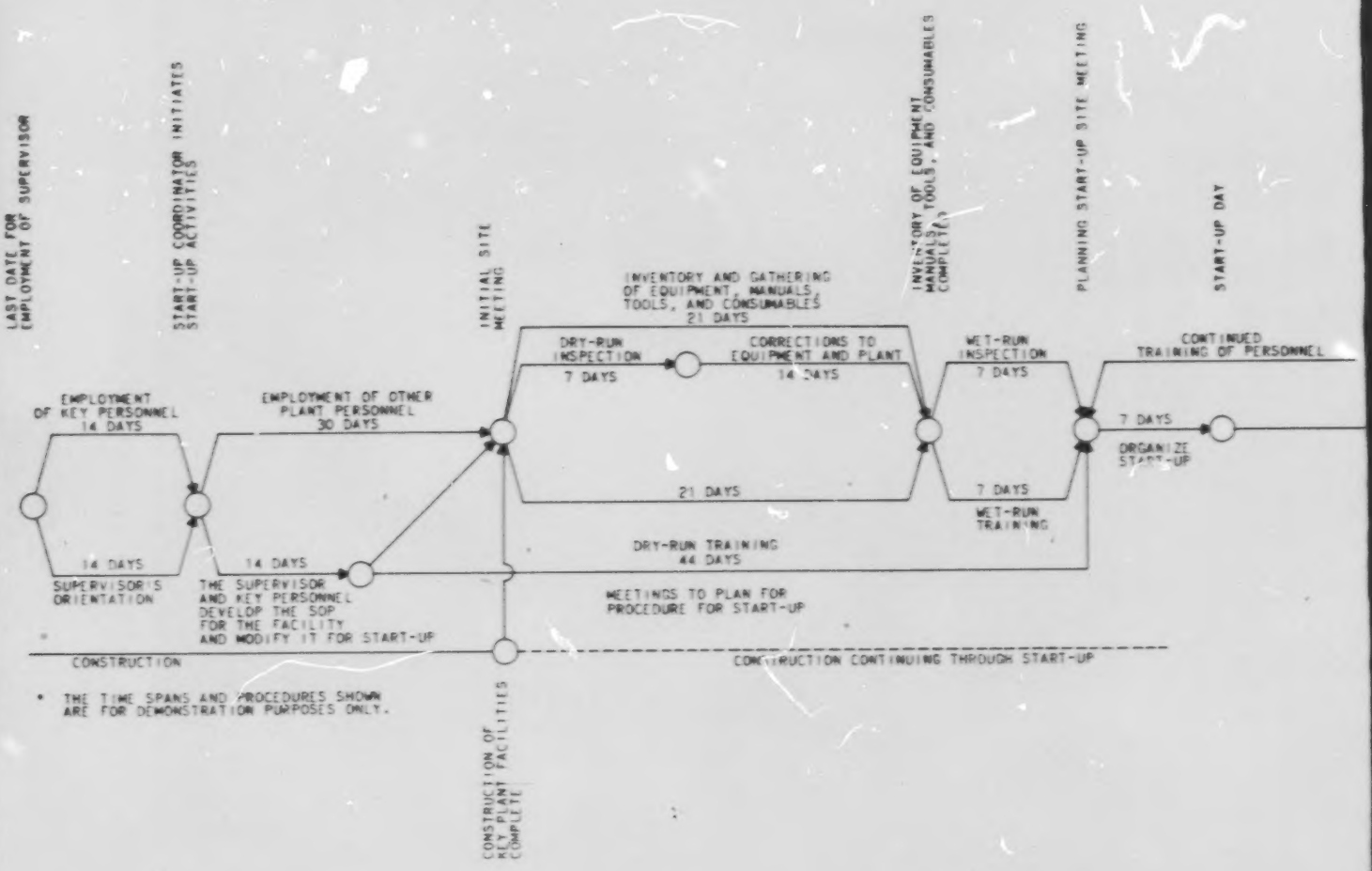
The following is a list of the topics and activities contained in this section. They are presented in a sequence that should lead to a successful start-up if proper consideration is given to the guidance discussed in this section. Figure No. 1, Start-Up Timetable of Events, is an illustration of the following topics and activities. Although it is for a large plant, it can be reduced or enlarged to correspond to any size or type of plant, process, or unit.

1. Employ Treatment Plant Supervisor who should:
   - A. Develop a working relationship with the contractor's project engineer and equipment suppliers.
   - B. Study construction schedules and plant layouts.
   - C. Initiate start-up planning and scheduling.

2. Employ assistant treatment plant supervisor, chief operator, chemist, and/or other key plant personnel who should:
   - A. Study plant layouts.
   - B. Study their individual responsibilities and activities.
   - C. Assist the Treatment Plant Supervisor with start-up preparations.

3. Develop Standard Operating Procedures (SOP) to include:
   - A. Shift schedules.
   - B. Laboratory sampling and testing schedules.
   - C. Plant record keeping procedures.
   - D. Areas of responsibility.

4. Employ plant operators, mechanics and electricians meeting qualifications based on the Environmental Protection Agency and State Regulatory Agency criteria.


LAST DATE FOR EMPLOYMENT OF SUPERVISOR
START-UP COORDINATOR INITIATES START-UP ACTIVITIES
INITIAL SITE MEETING
INVENTORY AND GATHERING OF EQUIPMENT, MANUALS, TOOLS, AND CONSUMABLES 21 DAYS
INVENTORY OF EQUIPMENT MANUALS, TOOLS, AND CONSUMABLES COMPLETE
PLANNING START-UP SITE MEETING
START-UP DAY
EMPLOYMENT OF KEY PERSONNEL 14 DAYS
EMPLOYMENT OF OTHER PLANT PERSONNEL 30 DAYS
DRY-RUN INSPECTION
7 DAYS
CORRECTIONS TO EQUIPMENT AND PLANT
14 DAYS
WET-RUN INSPECTION
7 DAYS
CONTINUED TRAINING OF PERSONNEL
7 DAYS
ORGANIZE START-UP
21 DAYS
7 DAYS
WET-RUN TRAINING
14 DAYS
SUPERVISOR'S ORIENTATION
14 DAYS
THE SUPERVISOR AND KEY PERSONNEL DEVELOP THE SOP FOR THE FACILITY AND MODIFY IT FOR START-UP
DRY-RUN TRAINING 44 DAYS
MEETINGS TO PLAN FOR PROCEDURE FOR START-UP
CONSTRUCTION
CONSTRUCTION CONTINUING THROUGH START-UP
CONSTRUCTION OF KEY PLANT FACILITIES COMPLETE

* THE TIME SPANS AND PROCEDURES SHOWN ARE FOR DEMONSTRATION PURPOSES ONLY.

FIGURE NO. 1

START-UP TIMETABLE OF EVENTS

5. Employ custodial, clerical and/ or individual laboratory personnel.

6. Modify SOP for plant start-up and minimize modifications from normal operating procedures.

7. Hold initial site meeting to coordinate start-up schedule with construction schedule.

8. Inventory and gather equipment manuals, tools, and consumables following the plant operation and maintenance manual and the equipment manufacturer's recommendations.

9. Conduct Dry-Run Inspection to ensure that:
   A. The installation of the equipment is checked and corrected if necessary.
   B. The construction of the plant structures is checked and corrected if necessary.

10. Conduct On-Site Dry-Run Operator Training in:
   A. The operation and maintenance of equipment and tools.
   B. The laboratory sampling and testing procedures.
   C. The plant layout and start-up responsibilities.
   D. The plant safety.

11. Conduct Wet-Run Inspection of:
   A. The equipment for proper operation.
   B. The piping and valves for leaks.
   C. The laboratory testing equipment.
   D. The monitoring and flow measuring instruments.

12. Conduct On-Site Wet-Run Operator Training
   A. Instruct personnel in:
      (1) The operation of the equipment under load.
      (2) The capabilities and limitations of the equipment.
   B. Conduct tours of similar plants.
   C. Institute buddy training with other plants in the area.
   D. Institute education from Federal and State training programs.

13. Hold Start-Up Planning Site Meeting to:
    A. Review start-up sequence and activities.
    B. Discuss responsibilities of all personnel and involved parties.
    C. List persons to be present during start-up.
    D. List persons to remain on call during start-up.
    E. Discuss emergency action procedures.

14. On start-up day, place start-up procedures into action.

The start-up of any municipal treatment facility is a complex operation requiring careful planning, effective coordination, and detailed preparation to maximize the treatment plant's efficiency and to minimize problems. The information provided in this section should be sufficiently general to apply to any wastewater treatment facility process or unit regardless of type and size. The details of any start-up procedure will, of course, have to be tailored to a specific facility, process, or unit. Giving consideration to the guidance contained in this section will help ensure that no important activities are overlooked during preparation for start-up. This section also contains considerations for organizing productive site meetings prior to start-up, providing effective on-site operator start-up training, and minimizing problems that might arise when plant construction is continuing while a portion of the facility is being started up.

STAFFING

A major consideration before start-up is the selection of personnel to operate the wastewater treatment facility. To aid in the selection of personnel, the U. S. Environmental Protection Agency (EPA) has developed two manuals entitled "Estimating Staffing for Municipal Wastewater Treatment Facilities," Contract No. 68-01-0328, and "Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Facilities," Contract No. 14-12-462. These manuals discuss the skills required by the plant personnel, plant staff organization, and the means to determine the necessary number of plant personnel. One of the most thorough methods for determining the necessary number of plant personnel presented in the staffing manuals is by task analysis. Briefly, this method consists of making an analysis of the tasks or jobs that are to be performed in the wastewater treatment plant and then each task or job is assigned a skill requirement. The analysis provides information on the skills and qualifications necessary to perform each task.

The supervisor of the treatment system should be selected well in advance of plant start-up to observe construction of the facility, become familiar with the plant layout and equipment, and employ and organize the plant personnel. (See Figure No. 1, Page 4.) The

supervisor should review with the project engineer: the engineering drawings, process concepts, the O & M Manual, and equipment layout. In addition, the supervisor of the wastewater treatment plant:

1. Has the responsibility for the administration, operation and maintenance of the entire plant.

2. Exercises direct authority over all plant functions.

3. Develops and initiates changes in plans and procedures of operation.

4. Organizes and directs operating personnel's activities and responsibilities .

5. Inspects plant regularly.

6. Analyzes and evaluates plant performance.

7. Controls and recommends expenditure of funds.

8. Maintains effective channel of communications and relationships with employees, public officials, and the general public.

The supervisor should have invested in him the authority to speak for the owner. However, since the supervisor will have no direct authority over the contractor or manufacturer's representative, it is very important that he establish good relations with these persons in order to learn as much as possible about the plant and its equipment.

If possible, the plant operators should be employed well before start-up in order that they may participate in on-site training. The operator may be called upon to perform any combination of tasks for controlling operation of the plant. These tasks may include:

1. Controlling flow and processing of wastewater and sludge.

2. Monitoring gages, meters, and control panels.

3. Analyzing meter, gage, and control readings and test results to determine process requirements.

4. Operating pumps, gates, valves and engines to control and adjust flow and treatment processes.

5. Collecting samples and performing laboratory tests.

6. Performing maintenance on equipment.

7. Making operating decisions in the absence of supervisory personnel.

Many states require that the operators of a sewage treatment plant be certified by the state. The state certifies that the operator is familiar with sewage treatment processes and operations. As many certified operators as needed should be employed to ensure that the above considerations and the state requirements are met.

In smaller wastewater treatment plants, the operators may perform mechanical and electrical maintenance, and laboratory sampling and testing. If the plant staff is divided into individual positions of operators, mechanics, electricians, and laboratory personnel, these positions should also be filled before start-up and the personnel properly trained in their respective duties and responsibilities and familiarized with the plant layout and equipment. For the purpose of this manual, these individual positions will be termed as operators.

All other staff positions such as custodial and clerical should also be filled before start-up.

STANDARD OPERATING PROCEDURES

Developing proper operating procedures during start-up will help eliminate many of the problems with processes and equipment that plague poorly operated wastewater treatment plants. By using the plant's O & M Manual, the supervisor, with other key plant personnel and the project engineer, should develop the standard operating procedures. The standard operating procedures should include:

1. Each shift schedule and procedures for transferring plant operations from one shift to another:
   A. The number of men required for each shift.
   B. The operator's individual responsibilities.
   C. The schedule of daily and nondaily tasks to be performed.

2. The schedule of laboratory sampling and testing.

3. The procedure for recording:

A. The plant operations and maintenance activities.
B. The maintenance schedules.

4. The procedures for changing the operation of the facilities.

5. The plant staff organization.

The standard operating procedure should be reviewed and revised periodically by the wastewater treatment plant management. To aid in developing the standard operating procedures, the EPA is presently developing a "Guide for Developing Standard Operating Job Procedures for Wastewater Treatment Plants," Grant No. 900253.

During start-up, the standard operating procedure may have to be modified. The supervisor should try to arrange the start-up shift schedule as close to the normal operating schedule as possible. Key personnel such as the shift foreman, project engineer, and start-up experts may be called upon to work more than one shift. Extra personnel may also be required for one or more shifts due to the increased work load that accompanies start-up. In small plants, where the maintenance force is available on one shift only, the force should be on 24-hour call during start-up.

The procedure for shift transfer should not have to be modified a great deal for start-up. The new shift should be provided with laboratory test results, process readouts, visual inspection data, any control action taken, and any other pertinent data needed to evaluate the condition of the treatment process.

During start-up, the supervisors and shift foremen should meet with their counterparts to review the shift log and discuss any unusual conditions or problems. They should review all new operations and maintenance forms during start-up to ensure the forms are being completed correctly by the treatment plant personnel. The plant supervisor, acting as the start-up coordinator, should see that all start-up information or special instructions are properly transferred from one shift to another.

The standard operating procedures should detail the schedule of laboratory sampling and testing. These procedures should be introduced to the operating personnel by the plant chemist, lab technician, or chief operator. The operator's performance in sampling and testing should be reviewed in order to prevent any bad practices from developing into routine operational procedure. The importance of accurate sampling and testing as a process control tool and its importance during start-up should be explained to all the operating personnel. The schedule of laboratory sampling and testing should provide for: (1) the type

of testing, (2) the time of testing, (3) the quantity of samples, (4) the point from where the sample is to be obtained, if not a composite sample, and (5) the frequency of sampling and testing. During start-up, some tests may be run more often than normal, and sampling points may have to be changed. The supervisor should see that the start-up schedule for sampling and testing is written and reviewed with the key plant personnel. The EPA has prepared a manual entitled "Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities," EPA-430/9-74-002, to provide information on what an individual wastewater treatment plant's laboratory needs are.

Proper plant records during and after start-up are essential to ensure that the treatment plant will operate efficiently. As mentioned previously, the records should include the laboratory test results, any control action taken, and any specific tasks performed. All unusual conditions observed should be recorded for future reference. Figure No. 7 in "Considerations for Preparation of Operation and Maintenance Manuals," EPA-430/974-001 is a sample of a portion of the standard operating procedure, the daily operating log. The supervisor should supplement the daily log with the number of men on each shift and their responsibilities and duties, and provide a schedule for nondaily tasks to be performed.

SITE MEETINGS

The objectives of start-up site meetings are to produce cooperation and understanding between the different parties involved with start-up by providing a means to: (1) schedule events, (2) inform all affected parties of any action to be taken, and (3) discuss and solve problems and conflicts of interest. (See Figure 1, Page 4) The major site meetings are referred to as the:

1. Initial
2. Dry-Run Inspection
3. Wet-Run Inspection
4. Start-Up Planning
5. Start-Up Day

Initial Site Meetings

The initial site meetings between the plant superintendent, contractor's project engineer, and the equipment supplier are to coordinate the start-up schedule with the construction schedule.

The supervisor should request that he be allowed to observe all installation, inspection, and pretesting of the plant equipment. This procedure will enhance the supervisor's knowledge

of the facilities and will also allow him to note any discrepancies he feels should be brought to the attention of the contractor's project engineer, equipment manufacturer's representative, or owner as he deems appropriate.

When construction is well underway, the supervisor should meet with the above persons and request that he be allowed to take the treatment plant personnel through the plant and familiarize them with the treatment plant equipment. This tour will require written approval from the contractor if he intends to operate the equipment unless that particular piece of equipment has been turned over to the owner as being "substantially complete." The supervisor should also request the equipment manufacturer's representatives to assist in training the plant operators in the maintenance and operation of the equipment. The supervisor can then arrange a schedule for the training of the plant operators and testing of the plant facilities.

Dry-Run Inspection Site Meetings

The dry-run inspection site meetings should be attended by the contractor, manufacturer's representatives, and the supervisor. The supervisor should record the actions that take place in the meeting. A form such as Figure No. 2, Sample Pre-Start-Up Inspection Record, will be of help during the inspection of the facilities and can be used as a permanent record for the plant's log book. The supervisor should have a copy of the manufacturer's literature on the installation, inspection and pretesting of their equipment. This information will enable the supervisor to become more familiar with the plant equipment and help him to notice any deficiencies that are present.

During these meetings, the supervisor with the project engineer should see that the manufacturer's representative checks the equipment for proper mounting, direction of rotation or travel, proper lubrication with the type of lubricants recorded and properly filed, clearances, alignments, undue noise and vibration, safety devices, and general operation. The supervisor and project engineer should see that the contractor removes all rags, stones, paper and other debris; that the piping is inspected for obstructions; that all piping and line connections are checked for leaks; that all gates and valves are checked for operation and seating; and that all safety chains and guards are in place.

The supervisor should also see that all equipment is properly broken in, that all equipment not to be used immediately is properly protected, and that the laboratory equipment is inspected for proper operation and calibration.

The inspection party should see that the malfunctions are scheduled for corrective action and a time is arranged for the operator's dry-run training and the wet-run testing of the

PLANT NAME AND LOCATION

EQUIP. NO.	EQUIP. DESCRIPT.	DRY RUN TEST AND CORRECTIVE ACTION	DATE	WET RUN TEST AND CORRECTIVE ACTION	DATE	CERTI-FIED OK
1001	COMMINUTOR	OK	1/23	OK	2/17	2/17/65
1057	RAW SEWAGE	LOOSE MOUNTINGS -				
	PUMP #1	CONTRACTOR WILL COR	1/23	UNDUE VIBRATION -	2/21	3/5/65
		RECT BY 1/24/65		SUPPLIER WILL FIX BY		
		IMPELLER CRACKED -	1/23	3/3/65		
		SUPPLIER WILL REPLACE				
		BY 2/3/65				
	GRIT CHAMBER	OK	1/23	DEAD SPOT -	2/17	2/18/65
	#1			CONTRACTOR WILL FIX		
				BY 2/18/65		
	CONNECTION	OK	1/23	PRESSURE LEAK -	2/17	2 19/65
	OF PIPE			SUPPLIER WILL REPAIR		
	TO RAW			BY 2/19/65		
	SEWAGE					
	PUMP #4					

FIGURE NO. 2

SAMPLE PRE-START-UP INSPECTION RECORD

facilities. Note: This manual's section on on-site operator training will present detailed considerations of the operator's training.

INVENTORY OF EQUIPMENT, MANUALS, TOOLS, AND CONSUMABLES

Prior to start-up the following items should be on hand, properly inventoried and stored by the supervisor and his staff:

1. A facility operation and maintenance manual.
2. A complete set of as-built drawings.
3. Construction specifications.
4. An indexed collection of construction photos.
5. The manufacturer's literature on operation and maintenance of his equipment, including parts list, component specifications sheets and drawings, and schematic drawings of the components supplied.
6. Manuals and literature deemed appropriate for plant operation and efficiency. (See the plant's O & M Manual for a partial list.)
7. Laboratory glassware, equipment, and chemicals needed in process control.
8. All tools and equipment needed for plant operation and maintenance.
9. All safety equipment.
10. Chemicals needed for process control and operation.
11. Spare parts for each piece of equipment as recommended by manufacturer.
12. Grease and oil needed for maintenance and operation of equipment.

The plant's O & M Manual should contain a list of similar items tailored for a specific plant. Most of these items should be on hand prior to testing the equipment.

Wet-Run Inspection Site Meetings

The wet-run inspection site meetings generally should occur after the wastewater treatment plant's owner has accepted the facility or unit as being "substantially complete."

By accepting the facility or unit, the supervisor and his staff will be free to operate the equipment on their own schedule. The contract document will call for a warranty period from the contractor and equipment manufacturer and, therefore, the wet-run inspection and testing should be done as early as possible to enable corrections to be made promptly and before actual start-up. If possible, the supervisor should have the equipment manufacturer's representatives present during the wet-run inspection. His input will be valuable to the supervisor and his staff.

The equipment manufacturer's instructions should be followed when inspecting and pretesting his equipment. The wet-run inspection should include:

1. Checking all piping and valves for leaks.
2. Inspecting operation of all gates and valves.
3. Inspecting all pumps.
4. Operating all mechanical devices under hydraulic load.
5. Inspecting chlorination facilities.
6. Observing laboratory sampling and testing procedures.
7. Checking all electronic/pneumatic instrumentation for proper operation.
8. Inspecting all flow meters, temperature and pressure indicators.
9. Inspecting all weir levels and adjusting for start-up.

All deficiencies found during the inspection and testing should be corrected before start-up. The supervisor and contractor's project engineer should then schedule a start-up planning site meeting.

Start-Up Planning Site Meeting

The supervisor should inform the persons who are to be present at the start-up planning site meeting of the date, time, and location of the meeting. The supervisor should provide persons present with the meeting agenda and any topics that they may be called upon to discuss. The supervisor, acting as the start-up coordinator, should have discussed with his staff, and the contractor's project engineer, the procedure for start-up and incorporated their comments prior to the meeting. The site meeting to prepare plans for plant start-up should include the contractor's project engineer, the treatment plant owner's representative, the plant supervisor, start-up consultants, the assistant supervisor, operations supervisor, maintenance supervisor, chemist, consultant's construction administrator on the project, contractor's job superintendent, and any representatives from manufacturers of key or unusual treatment units or processes.

At the meeting the supervisor, again acting as coordinator, should accomplish the following items:

1. Select a tentative start-up date.
2. List the persons who should be on hand at start-up.
3. Give the individual responsibilities at start-up.
4. Outline the events for start-up.
5. State who will remain on the site during start-up and who should remain on call.

The start-up coordinator should develop a timetable of events showing all activities from initial plant start-up to full operating efficiency. An illustration of a Timetable of Events is shown in Figure No. 1, Page 4.

Start-Up Day Site Meeting

At the start-up day site meeting, the contractor's project engineer and equipment suppliers should be on hand not only to ensure that the treatment equipment functions correctly but also to continue training the operating personnel. Any plant activity during start-up such as sludge pumping and vacuum filtration, which may not be common to all operating shifts, should be observed by the key plant personnel from all shifts. All operator functions should be monitored and critiqued by the supervisor so that bad practices are not allowed to develop as standard operating procedure. Maintenance support from other municipal divisions and local repair services for equipment should be alerted when the plant is ready for start-up.

ON-SITE OPERATOR START-UP TRAINING

In order to achieve the treatment objectives of the plant, it is necessary to have skilled plant operators. The supervisor, project engineer, and the appropriate equipment suppliers should conduct a series of tours through the plant for the operating personnel. The purpose of these tours is to familiarize the personnel with the plant and train them in their operation and maintenance responsibilities. The tour party should be tailored according to the operator's experience or responsibilities in order to keep the group manageable and to ensure that the training objectives are met. Training should be separated into Dry-Run Training (without any water or wastewater in the plant) and Wet-Run Training.

The supervisor should be responsible for organizing the different groups, instructors and timetable. Considerations should be given to the fact that the instructors may be available for only a few days and, therefore, the supervisor should take steps to organize the operator's training around the instructor's schedule. An example of the operator's training program may look something like this:

Tuesday, October 20, 1972

First Group - Primary Clarifiers

1. N. Royal
2. J. Mohr
3. W. Roberson

Instructor - J. Staples (Equipment Supplier, Inc.)
8:00 - 12:00 - Operation and maintenance; emergency procedures

Second Group - Laboratory

1. A. Ingram
2. J. Ballard
3. G. Mills
4. O. O'Donnel

Instructor - C. West (Chemist)
8:00 - 12:00 - Sampling and testing; operation, calibration and maintenance of equipment; test results and procedures for corrective action; log book

Dry-Run Training

The operator's dry-run training should provide the operator with instruction in all the various unit operations of the treatment plant, in the performance of his duties, and inform him of his responsibilities. The supervisor or foreman should have the construction drawings and the plant's Operation and Maintenance Manual to assist in the explanation of the operations of the treatment facility. The dry-run training should also familiarize the operating personnel with the equipment layouts, piping arrangements, remote monitoring equipment and process control equipment.

The operator should be provided with instruction in the execution of his specific duties. If possible, the operator should be shown by actual demonstration how to perform preventive maintenance on the various pieces of equipment he must operate. The importance of scheduled maintenance to prevent damage to the plant equipment should be emphasized.

Wet-Run Training

The wet-run training will strengthen the operator's understanding of the plant's treatment processes and will demonstrate how the equipment functions under hydraulic load. The operating personnel should also receive instruction in the role each piece of equipment has in the overall treatment objectives of the wastewater treatment plant. If possible, the supervisor should supplement the on-site training with:

1. A tour of similar plants or processes in the area or a pilot plant.

2. Buddy training, in which the operator is placed in a plant with an experienced operator performing the same tasks and having the same responsibilities as he will have.

3. Short courses offered by the state, federal, or local agencies or by holding classroom instruction himself.

NOTE: The EPA's "Operation of Wastewater Treatment Plants," Technical Training Grant No. 5TT1-WP-16-03, is a home study course but is also a useful reference for classroom training.

SAFETY

Accidents don't just happen -- they are caused, and during start-up the potential for accidents is increased. Some factors contributing to this potential increase are:

1. Personnel unfamiliar with equipment and operating procedures.

2. Empty tanks and basins.

3. Improperly installed equipment.

4. Inadequate lighting, ladder placement, handrail locations and equipment layout.

5. Personnel exposed to electrical and mechanical hazards due to initial operating adjustments.

6. Personnel unfamiliar with proper chemical handling, including chlorine.

7. Inadequate tools for repairs.

The wastewater treatment facility should have a safety program underway before start-up. Safety meetings with the plant personnel should be held routinely to discuss hazards in the plant. Some of the hazards within the plant will be exposed during the operator's tour through the plant and during the dry- and wet-run training. Any hazards identified by the tours and training should be corrected before start-up. Signs, posters, and physical barriers should be used to designate hazardous areas of the plant if corrective action is to be delayed.

Some means of motivating the personnel toward safety should be established such as bonuses, medallions, and time off. Other potential hazards such as diseases, lifting of equipment, and burns and cuts should be dealt with through the operator's training in safety, first-aid and health.

The operator's training in the handling of chemicals, especially clorine, should be thoroughly examined before start-up. A trial run in the connection and the use of the chlorine facilities should be carefully monitored by the supervisor and a qualified chlorine expert. The Water Pollution Control Federation's MOP No. 1, "Safety in Wastewater Works," and the Chlorine Institute's "Chlorine Manual." 4th Edition, should be used in the operator's training in the handling of chlorine.

The Safety section of the plant's O & M Manual should contain an in-depth discussion of safety along with a recommended list of safety equipment for the plant.

The Safety section of the O & M Manual in conjunction with other safety manuals, such as the Water Pollution Control Federation, MOP No. 1, "Safety in Wastewater Works," should be thoroughly reviewed with the operators before start-up. The EPA is presently developing a safety manual entitled "Safety in the Design, Operation and Maintenance of Wastewater Treatment Works," Contract No. 68-01-0324, to be of assistance in developing and operating a plant safety program.

Before start-up, all personnel should have a complete physical and be immunized against waterborne diseases. The safety equipment listed in the plant's O & M Manual such as gas masks, safety clothing, and first-aid kits should be inventoried and operational. The local hospitals and police and fire departments should be notified of the chemicals that will be used at the plant and their telephone numbers posted in a conspicuous place.

The accident report forms and the procedures for treating injuries also should be established prior to start-up.

CONSTRUCTION CONTINUING DURING START-UP

At the start-up planning site meeting, it may be decided that construction of the entire plant does not have to be completed before start-up can be initiated. It is not uncommon for certain construction and equipment installation to be continuing when the plant or a portion of the plant is placed into operation. Whenever this condition exists, a careful analysis should be made to ensure that start-up can, in fact, take place.

The importance of the following recommendations is shown by the following case history: Recently, a failure of communication and understanding between the contractor and the plant supervisory staff, in conjunction with other complications, resulted in the complete disruption of plant operations. As a result, the waste into the plant was bypassed into the receiving waters for a number of days. The pollution of the receiving waters was great enough to cause public officials to forbid public or private use of the water in the area for a period of some 13 to 14 days. Further study of this situation reveals that it could have been avoided if caution had been exercised and the lines of communication had been established prior to starting up the new facilities. From this study, the following recommendations have been prepared.

The contractor and equipment suppliers should assure the supervisor and his staff that there will be no unannounced interruption of electrical power due to construction schedules, that all the necessary equipment is installed correctly and operating properly, and that the plant personnel will not be subjected to any undue safety hazards.

The contractor and plant supervisor should coordinate all their activities. They should develop a timetable of events for their projects and coordinate each other's special needs while construction and start-up are proceeding simultaneously. The contractor and supervisor must also anticipate contingencies that might occur. The access roads, hallways, or steps may be blocked due to the unloading of materials; parking problems and traffic problems might arise due to shifts being changed simultaneously; and storage of supplies such as paint, gasoline, and chemicals may conflict with access to other supplies.

The supervisor and contractor should define in writing their respective responsibilities for men, machines, and areas in case an accident to men, machines, or structures should occur. For example, if the contractor is having equipment and supplies delivered to the site, the agreement would indicate where deliveries should be made and stored, thus avoiding possible damage to buried lines or cables from heavy equipment, keeping valves or lines from being inadvertently covered, and ensuring access to certain areas needed both by the contractor's and supervisor's personnel. A procedure should be included in the agreement to clarify responsibilities in cases where problems arise beyond the scope of the agreement.

The contractor and supervisor not only should define their responsibilities but also should define who is in charge in their absence. It is important that the person in charge be defined so as to give guidance and answer questions as required. The areas where the contractor's or supervisor's personnel should not go should be clearly indicated with physical barriers and signs.

Safety is of the utmost importance when construction is continuing during start-up. Hazards to personnel as well as the hazards to any biological processes are greatly increased, and the recommendations in the safety portion of this section should receive added emphasis under these conditions. Communication between the contractor and his personnel and the supervisor and his staff is absolutely necessary to help ensure no conflicts of interest will result and that personnel will not be subjected to any undue hazards.

SECTION III
START-UP OF THE PRETREATMENT, PRIMARY TREATMENT, AND CHLORINATION FACILITIES

Pretreatment and primary treatment facilities are the key to proper operation of conventional secondary treatment processes and sludge handling facilities. These facilities screen out debris and remove grit, grease, and settleable solids, all of which are harmful to the biological treatment processes and can damage plant equipment. Although the start-up of these facilities is often a "push-button" operation, proper inspection and pretesting of these units can eliminate many problems that occur during the start-up of wastewater treatment plants. Proper start-up of the pretreatment, primary treatment, and chlorination facilities will also help ensure an efficient start-up and maximize overall treatment plant efficiency.

This section gives consideration for starting up these facilities in regard to the overall wastewater treatment plant objective. The guidance is general enough to apply to any of the units regardless of any particular type of unit, although the guidance does not, nor is it intended to, replace or duplicate an individual equipment manufacturer's instructions or recommendations. The manufacturer's instructions and recommendations should be consulted whenever installing, inspecting, pretesting, maintaining, or starting his equipment. It is assumed that the previous section's considerations concerning preparation for start-up have been developed.

Common operating problems and their solutions not discussed in this manual can be found in the EPA's "Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants," Contract No. 68-01-0107, and the WPCF's MOP No. 11, "Operation of Wastewater Treatment Plants." Each treatment plant's O & M Manual should also contain valuable information to help solve operating problems.

SCREENS

The purpose of the screens is to remove or retain the coarse sewage solids which are likely to produce nuisances and create problems in the operation of pumps, raking mechanisms, or other mechanical facilities.

The screens are either manually or mechanically cleaned and the debris removed is disposed of by burial, incineration or, in some cases, by being placed in grinders or shredding devices and returned to the plant influent. The areas around the screens should be cleaned periodically of any spillage to help prevent accidents and help eliminate insect and odor nuisances.

Inspection and Pretesting

The manually cleaned bar screens should be inspected for proper installation and a schedule provided for cleaning of the screens during start-up and normal operation.

The mechanically cleaned bar screen should be checked to ensure that it has been installed properly and according to the equipment manufacturer's instructions, the operating interval is suitable for start-up conditions, and the drive mechanism has been properly lubricated and the lubricant type has been recorded and properly filed.

Once the screen mechanism is ready for pretesting, it should be turned through a complete cycle either by hand or jogging with electrical power to check for proper clearances and operation. The overload switch should be tested, if possible, to ensure that it will protect the drive mechanism if jamming of the screen occurs. The bar screen should then be run three to four hours to break it in and amperage reading taken and recorded.

Start-Up

During start-up the manually cleaned screens may require frequent attention due to large amounts of debris that may have accumulated in the collection system. Clogged screens can cause sewers to surcharge and may create septic wastewater in the collection system. This condition could result in a shock load on the treatment plant when full flow is resumed. Extra personnel may be needed to help remove the debris that collects on the screens if an unusually large quantity is expected.

The mechanically cleaned screens help overcome the problem of screen clogging. However, the screens may collect debris which the cleaning mechanism is unable to remove and periodic checks for proper screen operation should be scheduled. Depending on the direction of travel of the cleaning mechanism, the screen rakes can become jammed due to the debris that may collect at the base of the screen. Although this occurs infrequently, it should be especially watched for during start-up. The scraper mechanism that removes the debris from the rakes should also be inspected. If the scraper does not clean the rakes properly, the debris will be returned to the wastewater. The scraper mechanism should be adjusted as soon as possible to correct this problem if it occurs. The screen should also be inspected at frequent intervals during start-up to see that it is cleaning properly, that all alignments are maintained, that all bolts are tight, and that there is no undue vibration.

SHREDDING DEVICES

The comminuting or shredding devices overcome the problem of disposal of debris by cutting up the materials retained on the bar screens until they can pass through the screen

openings and flow into the treatment plant. The comminutor cuts up the material fine enough to prevent it from damaging the pumps or other mechanical equipment. The comminutor helps reduce odors and other nuisances often associated with bar screens, although the solids returned to the wastewater may produce more scum in anaerobic digesters.

Inspection and Pretesting

As mentioned previously (under the discussion of the bar screens), shredding devices should be installed in accordance with the manufacturer's instructions. The shredding devices should be inspected for proper clearances, alignment, and proper lubrication. The lubricant types should be recorded and properly filed and all required safety alarms and/or overloads should be operational.

After the shredding devices have been inspected for proper installation, they should be pretested by hand turning or electrically jogging the shredder through one complete cycle to check for proper clearances and alignment.

The shredder should then be broken in for three or four hours and inspected for tight mountings, vibration, overheating, and undue noise; and an amperage reading taken and recorded.

Start-Up

During start-up it is important to inspect the comminuting and shredding equipment to help protect the unit's cutters. The pre-start-up site meetings should have produced a frequency of inspection during and after start-up. Most units have traps placed in front of the comminutor to catch rocks and other heavy material. These traps should be checked and cleaned of all stones, sticks, and other unwanted material. The shredding area should be kept clean to help prevent accidents.

GRIT CHAMBERS

The function of the grit chambers is to remove sand, stones, cinders, and other heavy inorganic material. Grit chambers provide for the early removal of this material, thus protecting the mechanical equipment from abrasive action; reducing the formation of deposits in pipelines, channels and conduits; and reducing the amount of inorganics entering biological process units.

The gravity type grit chambers are usually rectangular in shape and rely on the velocity of the wastewater through the chamber for grit removal. The flow is usually maintained at

approximately one foot per second by the use of proportional weirs, orifices or flumes. This velocity allows the heavier inorganics to settle out and be removed, either manually or mechanically, and the less dense organic material to remain suspended.

A similar grit chamber uses air diffusers or impellers to create a controlled velocity spiral roll in the liquid which allows the heavier inorganics to settle out below the spiral roll and the organics to remain suspended. The velocity of the roll is controlled by the rate of air diffusion or by the impellers and the shape of the grit chamber.

Some grit chambers do not rely on velocity control but rely instead on mechanical means of removal. One type uses an inclined submerged reciprocating rake to resuspend the lighter organic material from the inorganic material. Another type uses the principal of centrifugal force to separate the materials. Both of these grit chambers separate and classify the settled materials more effectively than the velocity-controlled grit chambers.

Inspection and Pretesting

The inspection and pretesting of the grit chamber will vary according to the mechanical equipment used.

The inspection of the gravity type grit chamber will be oriented toward inspecting the construction of the basin and checking the flow control device for proper installation.

The spiral roll type of grit chamber should be inspected for construction and any debris left after construction. The driving equipment such as blowers or motors should be inspected for proper installation, tight mountings, and lubrication.

The mechanical grit chamber should be inspected for proper installation in accordance with the manufacturer's instructions. The manufacturer's literature should contain an equipment inspection checklist. In general, the lubrication should be checked and the lubricant type recorded and properly filed. All clearances and alignments should be checked carefully and the mechanism should be turned by hand, or electrically jogged, through one complete cycle. The unit should then be run for three to four hours and inspected for motor overheating, safety devices, proper installation of guards, undue noise and vibration, and mounting.

Another part of the grit chamber that will require inspection and pretesting is the grit removal mechanism. The mechanism should be inspected for tight mountings, proper lubrication, clearances, and alignment. This mechanism should have a short break-in period

before being placed into operation. Any electric motors involved should be inspected, tested, properly lubricated, and an amperage reading taken and recorded.

Start-Up

During start-up the grit chambers should be inspected periodically to ensure that the grit removing mechanism is operating properly. The frequency of grit removal may have to be increased during start-up due to possible large accumulation of grit in the collection system.

FLOTATION UNITS

Flotation is a unit operation which floats dissolved and suspended particles to the water surface where they are removed, either manually or mechanically. The particles are made to float by air bubbles that adhere to the particles causing the particles to float to the water surface. The flotation units have also been used as sludge thickeners. (See Section V, Sludge Conditioning.)

Flotation tanks are classified as air flotation, dissolved-air flotation, and vacuum flotation. The end result is the same in any of the units; that is, the release of air bubbles into the liquid to form a floating scum blanket. The air flotation tanks use air diffusers or impellers to add air bubbles to the liquid which creates a floating scum blanket.

The dissolved air flotation unit adds air in the wastewater while the wastewater is under pressure. The liquid is allowed to become supersaturated with air and then it is released to another tank at atmospheric pressure. The decrease in pressure allows minute bubbles to form throughout the liquid volume, thereby helping to create a scum blanket.

The vacuum flotation unit uses the same principle as the dissolved air unit. However, in this unit, the air is added to the wastewater in a tank at atmospheric pressure and allowed to become supersaturated with air. The wastewater is then transported to another tank where a vacuum is applied, thus reducing the pressure and once again allowing minute air bubbles to form, again resulting in the formation of a scum blanket.

Inspection and Pretesting

The flotation tank should be inspected and cleared of any debris that may have collected during construction. The tank should be checked for proper installation of the air lines, valves, and pumps if the flotation unit is a pressure or vacuum flotation tank. The air flotation tank should be inspected for proper installation of the impeller and motor or air lines, diffusers, and blower.

Regardless of the type of flotation tank, the sludge removal mechanism should be inspected for proper clearances and alignments and the flotation and sludge removal units should be lubricated according to the manufacturer's instructions and the lubricant types recorded and properly filed.

Before running the flotation for its three to four hour break-in period, the sludge removal unit should be electrically jogged through one complete cycle and the depth of the rakes in the water, the clearance and level of the rakes at the sludge trough, and the alignment of the rakes and drive mechanism checked. The pressure or vacuum pump should be inspected for tight mountings, smooth operation, overheating, undue noise or vibration, and proper clearances and alignments. Pressure and amperage readings should be taken and recorded.

Start-Up

During start-up the unit should be inspected periodically to ensure that the skimming mechanism is operating properly and that the scum blanket does not become too large or too thick to handle.

SETTLING TANKS

Settling tanks are commonly used not only in primary treatment of wastewater, but also as a unit operation in the secondary treatment processes of activated sludge and trickling filters. The purpose of the primary sedimentation tank is to remove the larger suspended solids and the floating material from the wastewater prior to discharge to the receiving waters or to the secondary treatment units. The primary sedimentation tank effectively removes from 50-65 percent of the suspended solids and from 25-40 percent of the BOD_5 from domestic wastewater. The secondary type settling tanks treat the biological unit's effluent. The operation is the same as the primary except the surface loading and sludge volume are usually less than the primary. The intermediate settling tank is used between trickling filters for improved efficiency and operates in the same manner as the primary and secondary settling tanks.

Inspection and Pretesting

The inspection and pretesting of the primary clarifier is particularly important because it is a major unit with many mechanical parts submerged during operation. The basin and piping should be cleared of all debris. All control gates and valves should be checked for smooth operation and proper seating and the sludge collector mechanism checked for proper alignments, clearances, and lubrication. The drive mechanism should be inspected for tight mountings, drive alignment, clearances, safety devices, and proper lubrication; the weirs

should be inspected for level. The manufacturer's literature should be reviewed to see that the mechanism has been installed, lubricated and is operating according to their instructions.

The mechanism should be run for three to four hours prior to letting wastewater in. The raking mechanism should be checked for proper clearance and smoothness of operation and the drive motor inspected for any undue noise, vibration, and overheating, and an amperage reading taken and recorded. During start-up the scum removal equipment should be checked to see that it is removing the scum properly.

Start-Up

During start-up of the primary clarifier, the raw sludge should be removed from the clarifier (settling tank) when it consists of four to eight percent dry solids as indicated by the total or suspended solids test. Sludge removed two times a day will normally be of this consistency. The sample of raw sludge is usually taken from a sludge pit before pumping. The sludge is mixed in the pit and a representative sample taken directly from the well. Samples are also collected from openings in pipes near the sludge pumps or from the pump itself. When pumping to digesters, the sludge should be as thick as possible and sludge withdrawal (pumping) rates should be low in order that water is not drawn into the sludge. As the sludge is being removed, it should also be checked for the amount of grit present. If appreciable amounts are present, then more frequent removal of grit is necessary and the grit removal equipment should be inspected.

Operating personnel should be trained in the clarifier operation and be provided with a schedule for sludge pumping during start-up and normal operation. When the sludge appears thin (appreciable amount of water) by visual inspection, pumping should be stopped. Although the total solids test is the only accurate means for determining the density of the sludge, it is too slow for control of routine pumping operations. Many operators use the centrifuge test for quick results and most experienced operators can visually determine if the sludge is the proper density to pump by sounding for the depth of sludge. Sounding for depth enables the operator to determine the sludge quantity to be removed and thus the time required for pumping to remove that quantity of sludge. The laboratory test should be run to verify the operator's judgment and for the plant operating records. Other laboratory tests should be run for plant operation and control such as the DO, BOD, Suspended Solids and Settleable Solids. The plant's O & M Manual should contain a list and frequency of the necessary laboratory tests for the clarifier. The procedures for running these tests are found in *Standard Methods*, and the WPCF's Publication No. 18, "Simplified Laboratory Procedures for Wastewater Examination"; these references should be included in the supervisor's list of necessary books and manuals for plant operation.

Three of the more common operating problems that may affect the operation of the sedimentation basins are too thick a sludge, septic sludge, and short circuiting.

1. If the sludge removal equipment operates erratically, it may be because of a thick sludge. After inspecting to see that some mechanical failure has not occurred, and a thick sludge has been identified, steps to remove the sludge should be taken. More frequent and controlled removal of the sludge should cure and prevent this condition. It may be necessary to dewater the tanks and remove the sludge by hand if there is a possibility of damaging the equipment.

2. If the sludge is not removed often enough, it may become septic, indicated by a "rotten egg" odor and possibly a rising sludge blanket. In this case, it may be beneficial to chlorinate the clarifier contents to reduce odors and delay the decomposition of the sewage while corrective action is being taken. Chlorinating the clarifier contents should be done with caution because it will affect any following biological processes. More frequent removal of the sludge will cure or prevent this condition if it is not the result of a mechanical failure.

3. Short circuiting is another problem that might occur at start-up. Short circuiting occurs when a high velocity area exists in the basin and can be indicated by a rising sludge, flow of sludge particles in the effluent, and septic sewage. Usually, proper baffling, weir type and elevation, and inlet design can prevent or reduce this problem by altering the flow regime within the clarifier.

CHLORINATION

Chlorine is a gas, heavier than air, extremely toxic, and corrosive in moist atmospheres. The gas is irritating to the mucous membranes of the nose, to the throat, to the lungs and heavy exposure can be fatal. All persons handling chlorine should be aware of these hazardous properties. The operator's on-site training, the Water Pollution Control Federation's MOP No. 1, "Safety in Wastewater Works," the Chlorine Institute's "Chlorine Manual," 4th Edition, the EPA's "Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants," Contract No. 68-01-0107, and the chlorine equipment supplier can help familiarize the operators with the hazards of chlorine and with the use of various pieces of

protective equipment such as oxygen systems. The operator's training should include instructions in the dangers of chlorine, the use of emergency equipment and repair kits, first aid, and the methods and procedures for handling chlorine containers.

Although clorine is primarily used as a disinfectant in wastewater plants, it has a variety of other uses also. In a prechlorination unit, chlorine is added for disinfection and odor control, but it can also be applied to reduce plant BOD load, to aid in settling, to control foaming, and to help remove oil. Throughout other points in the plant, chlorine may be added to wastewater for control and prevention of odors, sludge bulking, filter flies, corrosion, digester foaming, filter ponding, and as an aid in sludge thickening. Following all other treatment units and processes, chlorine is added primarily for disinfection.

Disinfection is strictly defined as the destruction of all pathogenic organisms. By destroying the pathogenic and nonpathogenic organisms, chlorine helps prevent nuisances such as odors from developing and protects municipal water supplies, bathing beaches, and other recreational areas from waterborne diseases.

Inspection and Pretesting

As mentioned under On-Site Operator's Training and the Safety section, an experienced individual in the use and handling of chlorine should always be on hand prior to start-up to guide the new operating personnel in the inspection and pretesting of the chlorine equipment. In general, the chlorination equipment should be inspected for installation and calibration, and the pressure readings should be recorded. The connections should be checked with ammonia water with the chlorinator only partially open. Having the chlorinator only partially open will aid the operator if he has to shut down the chlorinator quickly. All valve positions should be checked and the valves should be inspected for proper seating. Safety equipment and emergency repair kits should be on hand and inspected. The "Handbook of Chlorination" by George Clifford White, Chapter 3, discusses start-up of the chlorination equipment in detail.

Start-Up

Once the equipment has been inspected and pretested, start-up should produce few mechanical problems. The operator should measure the chlorine feed and chlorine residual and adjust the system to provide the required amount of chlorine residual determined by the supervisor, state, and/or federal regulatory agencies.

SUMMARY

The preceding sections have provided recommendations and procedures for starting up pretreatment, primary treatment, and chlorination facilities; however, the procedures are

not absolute. It cannot be stressed enough that the procedures should be used in conjunction with the manufacturer's recommendations and instruction and advice from experts in the field of wastewater treatment plant operation.

Before starting up any of the pretreatment, primary treatment, and chlorination units, they should be thoroughly inspected, pretested, and made ready for start-up. During start-up, it is important that the equipment be inspected periodically to ensure that the units are performing properly and to note any problems or indications of potential problems that might arise. The electric motors should be properly lubricated and the lubricant type filed; and readings such as pressure and amperage should be recorded both when the motor is under load and without load. The plant personnel should try to anticipate any contingencies that might occur during start-up and to plan for the proper corrective action to handle these problems.

SECTION IV
START–UP OF SECONDARY FACILITIES

The secondary treatment processes used in municipal wastewater treatment aid in providing the high degree of treatment required to ensure the protection of the receiving waters. Secondary treatment processes consist of complex biological systems that require a delicate balance of food and environment. Since it is during start-up that the microorganism population required for proper treatment is being developed, the start-up of secondary processes is more critical than their normal operation because of the increased need for process control. A proper start-up of the secondary process ensures maximum treatment efficiency from the initial day of operation.

This section provides considerations and techniques for starting up secondary treatment processes. The guidance is general enough to apply to any size or type of secondary treatment process. It is assumed that the previous sections' considerations on preparing for start-up and start-up of the pretreatment, primary treatment, and chlorination facilities have been incorporated into the start-up procedures.

Common operating problems and their solutions not discussed in this manual can be found in the EPA's "Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants," and the WPCF's MOP No. 11, "Operation of Wastewater Treatment Plants." Each treatment plant's O & M Manual should also contain valuable information to help solve operating problems.

ACTIVATED SLUDGE

The activated sludge process is a biological wastewater treatment process. The activated sludge, in general, consists primarily of bacteria, protozoa, and rotifers living in the sewage in the presence of dissolved oxygen. The activated sludge converts organic substances in finely divided, colloidal, and dissolved form into oxidized products and a settleable floc. This floc, now as activated sludge, is removed from the wastewater by sedimentation leaving a high quality effluent. The biological action is accomplished in aeration tanks where the organisms are maintained in an aerobic environment by introducing oxygen into a mixture of activated sludge and sewage. The settling of the floc is accomplished in secondary settling tanks.

Raw sewage does not contain sufficient organisms to properly stabilize the organics present in the wastewater; therefore, it is necessary to develop sufficient microbial mass (activated

sludge) and distribute and maintain the mass throughout the wastewater to accomplish the designed treatment. As the organisms feed on the organics and increase in number, they are removed from the aeration basin, and settled in a clarifier; appropriate portion is recirculated to the aeration basin to provide the desired mass of organisms needed to efficiently treat the wastewater.

The primary objective of start-up is to develop a proper microbial floc (activated sludge) as quickly as possible. This development will result in an increase in the reduction of biochemical oxygen demand (BOD_5) and a reduced load on the receiving waters as the activated sludge floc is settled and removed in the sedimentation tanks. A portion of this settled floc (activated sludge) is returned to the aeration tanks until a desirable concentration of organisms, expressed as mixed liquor suspended solids (MLSS), has been established in the process. Once this concentration is established, excess settled floc (activated sludge) is wasted to maintain the proper concentration of MLSS in the process.

The activated sludge process has various modifications which provide different approaches to biological waste treatment depending on the characteristics of the wastewater to be treated. Table 1 illustrates some of the differences in these process modifications. (Note the differences in MLSS concentration.)

It is essential that laboratory analysis and control schedules be provided and followed during start-up. Although the following procedures should apply to starting up any of the process modifications of the activated sludge process, the supervisor should take advantage of all the information available to him. The person(s) responsible for start-up should obtain the process design criteria such as influent flow, BOD_5 loading, sludge age, detention time, temperature and mixed liquor suspended solids (MLSS) concentration. The use of these parameters as control parameters should be discussed with the design engineer for his comment and for any corrections he feels should be made. Once the correct information has been obtained, the desired Start-Up MLSS concentration can be estimated. Using the design flow and design MLSS concentration and by measuring the actual flow and calculating the BOD_5 loading entering the basin, the desired Start-Up MLSS concentration in a single aeration basin can be determined.

$$\text{Design MLSS concentration for aeration basin to be started} \times \frac{\text{Actual Flow to the Basin}}{\text{Design Flow to the Basin}} \times \frac{\text{Actual BOD Concentration}}{\text{Design BOD Concentration}} = \text{Actual "minimum" Start-Up MLSS Concentration for a Single Basin}$$

Process Modification	Sludge Age (Days)	BOD Removal Efficiency %	MLSS, mg/liter	Application
Conventional	5-15	85-95	1,500 - 3,000	Low-strength domestic wastes, susceptible to shock loads
Complete - mix	5-15	85-95	3,000 - 6,000	General application, resistant to shock loads
Step-aeration	5-15	85-95	2,000 - 3,500	General application to wide range of waste
Modified-aeration	.2-.5	60-75	200 - 500	Intermediate degree of treatment where cell tissue in the effluent is not objectionable
Contact-stabilization	5-15	80-90	*(1,000 - 3,000) **(4,000 -10,000)	Expansion of existing systems, package plants, flexible
Extended-aeration	20-30	75-95	3,000 - 6,000	Small communities, package plants, flexible
Kraus process	5-15	85-95	2,000 - 3,000	Low-nitrogen, high-strength wastes
High-rate aeration	5-10	75-90	4,000 -10,000	Use with turbine aerators to transfer oxygen and control the floc size, general application
Pure-oxygen systems	8-20	85-95	6,000 - 8,000	General application, use where limited volume is available, use near economical source of oxygen

* Contact unit
** Solids stabilization unit

NOTE: The MLSS values are not for use as the design MLSS.

TABLE 1

MODIFICATIONS OF THE ACTIVATED SLUDGE PROCESS
(Similar to Wastewater Engineering, McGraw-Hill Company, Inc., 1972, Figure No. 12-3)

The above equation is for a single aeration basin. If there is more than one basin in the plant, the design MLSS will have to be varied accordingly to obtain the "minimum" Start-Up MLSS concentration for any one aeration basin. This proportioning to the basins is necessary in order to maintain the proper food-to-microorganism ratio (F/M) and sludge age. By starting only one or two basins, the other basins can be started using the activated sludge from the others as seed sludge and start-up of these basins should be accomplished more quickly and efficiently. (See Examples 1 and 2.)

The "minimum" Start-Up MLSS concentration is the concentration that should be built up before wasting any activated sludge during start-up. (If the flow into the plant is stepped in increments during start-up, then the Start-Up MLSS concentration will also have to be incremented accordingly.) It should not be necessary to change the value for the MLSS concentration obtained due to any temperature fluctuations or minor changes in flow, but by maintaining the "minimum" MLSS concentration value within plus or minus 10%, a manageable start-up with good efficiency should be possible. The optimum value for MLSS concentration will have to be determined by adjusting the return sludge rate and wasting rate, which changes the MLSS concentration in the basin, and by comparing the BOD_5 removal efficiency through the secondary process. The optimum value for MLSS concentration will be when the BOD_5 in the final clarifier effluent is minimized.

Ferric chloride or polymers can help develop the MLSS concentration by concentrating the solids used for recirculation while minimizing final effluent BOD_5 loading on the receiving waters. The quantity of chemical or polymer to be added to the settling tank can be determined in the laboratory by jar tests. Caution should be exercised when adding chemicals in order that toxic cation levels are not allowed to develop. Adding chemicals as coagulant aids may give erroneous values for MLSS concentration because some of the suspended solids may be chemical flocs and not biological flocs. It will be necessary to test for mixed liquor volatile suspended solids (MLVSS) concentration which would indicate the amount of biological suspended solids present and remove the chemical floc error.

Inspection and Pretesting

Before putting the preceding paragraph's information into effect, a responsible person should inspect and pretest the activated sludge facilities to ensure that:

1. All debris is removed from the basins and piping systems.

2. All gates and valves are opened and closed and checked for smoothness of operation and seating in the closed position.

3. The effluent weirs are checked for level.

4. All nozzle heads of the froth control system are open and on securely.

5. The inspection of the air system includes:
   A. Checking the air filter and condensation trap.
   B. Checking the air lines for leaks.
   C. Checking valves for proper and smooth operation.
   D. Inspecting the blower for proper lubrication, clearances, and safety guards.
   E. Inspecting the coupling from the motor for proper alignment.
   F. Inspecting the mounting of the motor and blower for tightness.
   G. Inspecting air gauges for proper operation and calibration.

6. The air headers are raised and lowered and checked for smooth operation.

7. The diffusers are inspected to ensure that the air can go through freely.

NOTE: Figure No. 2, Sample Pre-Start-Up Inspection Record, page 12 will be a useful form for inspecting and testing the facilities.

If mechanical aerators are used, they should be rotated first by hand to ensure proper alignment and smoothness of operation. The mounting of the unit should be carefully inspected to ensure it is fastened securely. The motor should be lubricated properly and the lubricant type recorded and properly filed. All electrical motors should be jogged to see that the wiring is connected correctly and that the motors are turning in the correct direction.

After inspecting the facilities for installation, operation, and calibration in accordance with the manufacturer's instructions, the facilities are ready for testing. The facilities should be "wetted down," preferably with domestic water and

1. The piping system should be inspected for leaks of either air or water.

2. The gates and valves should again be checked for seating.

3. The froth control system should be checked to see that the nozzles are spraying the correct pattern and in the proper area.

4. The air system and its safety devices should be inspected for proper operation. (The air pressure and amperage readings should be recorded and filed.)

5. The motors should be inspected for vibration, noise, and overheating, and an amperage reading taken and recorded.

After inspecting the air system for proper operation, run the system for three to four hours, inspecting periodically for any problems.

The inspection and pretesting of the final settling tank is discussed in Chapter III (Start-Up of the Pretreatment, Primary Treatment, and Chlorination Facilities).

Start-Up Procedure

Prior to start-up, a composite sample of the raw sewage to be treated should be obtained and a settleable solids test run. From this test, very carefully remove the filtrate and determine the BOD_5 and the Chemical Oxygen Demand (COD). The filtrate is used to approximate the primary clarifier effluent characteristics. The BOD_5 and COD tests should be performed on several samples in order to obtain a BOD_5 to COD relationship. This relationship allows the COD test to be used for process control in lieu of the much longer BOD_5 test during start-up. This test will enable a quick measure of the efficiency through the activated sludge treatment process and a quick means of estimating the ratio of organics (BOD_5) to the microbial population (MLSS) usually referred to as the food-to-microorganisms ratio (F/M). A normally operating plant typically has an F/M ratio of 0.2 to 0.5, except for extended aeration which operates at a lower F/M of 0.1 and less.

The BOD_5 to COD relationship should be used with discretion because there may be a change in the ratio of the two parameters, possibly caused by an increase in the nonbiodegradable organics or due to solids carryover, which could prohibit or invalidate such a relationship. To reduce the error between the COD/BOD_5 ratio, it may be useful to obtain another COD/BOD_5 ratio by testing the liquid portion of a Suspended Solids test for BOD_5 and COD (referred to as the Dissolved BOD_5 and Dissolved COD). The Dissolved COD/BOD_5 relationship will probably be more consistent than the other COD/BOD_5 ratio,

but it will take longer to obtain. Keep in mind that the Dissolved COD/BOD_5 ratio may not be the same for all areas of the plant; therefore, depending on the circumstances of start-up, the COD/BOD_5 ratio may have to be determined at a number of locations in the plant for start-up control. (Both the COD and BOD_5 tests should continue to be run during start-up to confirm the COD/BOD_5 relationship.) Once the process becomes operational, the COD test should be run as a useful process control tool although the BOD_5 is the standard quality control parameter required by most regulatory agencies.

On the second and third day after the effluent from the primary clarifiers begins entering the aeration basin, the BOD_5, COD, MLSS and sludge volume index (SVI) should be determined on samples from the aeration basin and the final clarifier. (The relationship between COD and BOD_5 of the influent may not be the same as that of the effluent; therefore, BOD_5 should be run daily.) The SVI is indicative of the settling characteristic of the floc in the final clarifier and will indicate the possibility of sludge bulking. Generally, an SVI in the range of 50-150 indicates a good settling sludge. Visual observation of the settleable solids test is also beneficial in obtaining information on the settling characteristics of the activated sludge in the final clarifier.

The following are examples of the preceding procedures:

EXAMPLE 1: MLSS DETERMINATION: SINGLE BASIN

Conventional Treatment

Single Aeration Basin

Design Conditions

Flow = 1 MGD

BOD_5 Loading = 37 lb. BOD_5/day/1000 ft^3 of basin

Temperature = 70° F.

MLSS = 1500 mg/l

BOD_5 Concentration = 150 mg/l

Actual Conditions

Flow = .75 MGD

BOD_5 Loading = 28 lb. BOD_5/day/1000 ft^3 of basin

Temperature = 65° F.

* BOD_5 Concentration = 150 mg/l

*Obtained from analysis on raw sewage, from analysis of clarifier effluent or from BOD_5/COD relationship.

"Minimum" MLSS concentration =

$$1500 \text{ mg/l} \times \frac{.75 \text{ MGD}}{1 \text{ MGD}} \times \frac{150 \text{ mg/l}}{150 \text{ mg/l}} = \underline{\underline{1120}} \text{ mg/l}$$

EXAMPLE 2: MLSS DETERMINATION: MULTIPLE BASINS

Conventional Treatment

Ten (10) Aeration Basins with 54,000 ft^3/basin

(Three to be started)

Design Conditions

Flow = 16 MGD

BOD_5 Loading = 37 lb/day/1000 ft^3 of basin

Temperature = 70°F.

MLSS = 1500 mg/l

Total Volume of Basins = 54,000 ft^3 x 10 = 540,000 ft^3

BOD_5 Concentration = 150 mg/l

Actual Conditions

Flow = 4 MGD

BOD_5 Loading = 31 lb/day/1000 ft^3 of basin

Temperature = 65° F.

BOD_5 Concentration = 150 mg/l

"Minimum" MLSS =

$$\frac{\text{Flow to basin(s) to be started/number or volume of basins}}{\text{Design flow to basin(s)/total number or volume of basins}}$$

$$\times \frac{BOD_5 \text{ Concentration to Basins}}{\text{Design } BOD_5 \text{ Concentration}} \times \text{Design MLSS} =$$

$$\frac{4 \text{ MGD/3 Basins}}{16 \text{ MGD/10 Basins}} \times \frac{150 \text{ mg/l}}{150 \text{ mg/l}} \times 1500 \text{ mg/l} = \underline{\underline{1250}} \text{ mg/l}$$

The number of basins required to be started under field conditions is determined by the flow. The design flow for Example 2 is 16 MGD to ten basins, or 1.6 MGD/basin if all basins are equal in volume. Therefore, 4 MGD would require 2.5 basins (4 MGD divided by 1.6 MGD/basin). Since it doesn't equal an even number of basins, use the next higher number

(in this example, 3 basins). Therefore, starting up three (3) basins will have a better food-to-microorganisms (F/M) ratio than if all ten (10) basins were used, or only one basin, and thus will have a more effective start-up.

The start-up of the activated sludge process can be accomplished by using seed sludge or raw wastewater to develop a suitable microorganism population expressed as mixed liquor suspended solids (MLSS).

1. The use of a seed activated sludge will provide the most reliable means of start-up. When available, enough seed sludge should be placed into the aeration basin to provide at least 500 mg/l of MLSS in order to handle the plant flow. Maximum aeration should be used during start-up to provide a minimum Dissolved Oxygen content of 2 mg/l and to aid mixing. With the seed sludge aerated, flow into the aeration basin should be introduced at approximately 10 percent of plant flow if possible and increased in daily increments of 10 percent if there is no indication of the process deteriorating. This will enable the treatment process to produce a quality effluent as the MLSS concentration is increasing.

2. If raw sewage is used, begin start-up of the activated sludge process by filling the aeration basin with the raw sewage, bypassing the primary clarifier. This will provide the greatest number of available seed organisms without seed sludge. The aerators should be operating before raw sewage is let into the basin to keep the diffusers from clogging and to provide mixing, and should be operated at a rate to maintain a minimum Dissolved Oxygen (DO) residual of 2 mg/l. The aeration basins, if possible, should then be bypassed for a period of approximately eight hours during which the raw sewage is being aerated. After approximately seven hours, the aerators should be turned off and the mixture in the basin allowed to settle for thirty to sixty minutes, after which additional raw sewage should be allowed to enter and displace the basin supernatant. The mixture should then be reaerated and allowed to settle as before. This practice should be continued until the MLSS is at least 500 mg/l at which time the aeration basins should be placed on continuous flow and the MLSS allowed to build up to the "minimum" MLSS as calculated. As the MLSS continues to increase, the aeration rate may be reduced if the

DO is greater than 2 mg/l. The DO test should be run frequently during this period, usually every two hours during start-up, to ensure that the oxygen requirements of the organisms are met.

Regardless of which of the above methods is used, no return sludge should be wasted during start-up; the sludge return pumps should be returning at a rate such that no sludge blanket will develop in the settling tanks. This procedure will ensure the maximum number of available organisms, as activated sludge will be returned to the aeration basin.

When the proper MLSS concentration is reached for full flow, the return activated sludge pumping rate should be adjusted. The estimated return sludge pumping rate can be determined from the settleable solids analysis:

% MLSS in the 60-minute settleable solids test expressed as the decimal equivalent x (Influent flow rate plus the return sludge flow rate) = Return Activated Sludge Pumping Rate

EXAMPLE 3: ADJUSTED RETURN SLUDGE PUMPING RATE DETERMINATION

Flow to Aeration Basin = 4 MGD

Return Sludge Flow = 2 MGD

Volume of MLSS in 60-minute settling test = 400 ml in 2 liters = 20% = .20

Therefore

Adjusted Return Sludge Rate = .20 x (4+2) MGD = 1.2 MGD

Adjusted Return Sludge Rate = 1.2 MGD x 695 $\frac{\text{GPM}}{\text{MGD}}$

= 835 gallons/minute

Therefore, the return activated sludge pumping will have to be reduced from 2 MGD to 1.2 MGD or 835 gallons/minute. This rate may have to be adjusted to maintain the proper MLSS in the aeration basin.

When the return sludge pumping rate has been established, sludge should begin to form a blanket in the settling tank. After the sludge blanket accumulates to approximately 1 foot above the tank bottom, the excess waste activated sludge pumping rate can be determined. The waste activated sludge pumping rate will also change the return sludge pumping rate.

EXAMPLE 4: WASTE ACTIVATED SLUDGE PUMPING RATE DETERMINATION

This can be determined in one of two ways:

1. Activated Sludge Plant with all basins operating.

Assume these values were obtained from laboratory analysis:

MLSS = 2800 mg/l (Used in Step (1))

Return Sludge, Suspended Solids = 5600 mg/l (Used in Step (6))

Influent, Suspended Solids = 60 mg/l (Used in Step (2))

Average Daily Flow = 4 MGD (Used in Step (2))

Volume of Aeration Basin = 0.55 MG (Used in Step (1))

Design Sludge Age = Mean Cell Residence Time = 5 days (Used in Step (4))

Return Sludge Pumping Rate = 835 GPM

Determine:

Step (1): lbs of Solids in Aeration Basin = MLSS (mg/l) x Volume of Aeration Basin (MG) x 8.34 $\frac{\text{lbs/MG}}{\text{mg/l}}$

$$= 2800 \text{ mg/l} \times 0.55 \text{ MG} \times 8.34 \frac{\text{lbs/MG}}{\text{mg/l}}$$

$$= \underline{\underline{12{,}700}} \text{ lbs. of Solids in the Aeration Basin}$$

Step (2): $\frac{\text{lbs}}{\text{day}}$ Solids Added by Primary Clarifier Effluent = Influent Suspended Solids (mg/l) x Avg. Daily Flow (MGD) x 8.34 $\frac{\text{lbs/MG}}{\text{mg/l}}$

$$= 60 \text{ mg/l} \times 4.0 \text{ MGD} \times 8.34 \frac{\text{lbs/MG}}{\text{mg/l}}$$

$$= \underline{\underline{2{,}000}} \text{ lbs/day Added by Primary Clarifier Effluent}$$

Step (3): Sludge Age (days) = $\frac{\text{MLSS in Aeration Basin (lbs)}}{\text{Solids Added by Primary Clarifier Effluent (lbs/day)}}$

$$= \frac{12{,}700 \text{ lbs}}{2{,}000 \text{ lbs/day}}$$

$$= \underline{\underline{6.4}} \text{ days}$$

Step (4): If the Sludge Age was less than the design value of five days, no wasting should be done. Under normal conditions, the sludge age will indicate when to reduce or increase the wasting rate.

The design sludge age

= 5 days; therefore, rearranging the equation in (3),

lbs. MLSS
to be maintained = Sludge Age x Solids added by Primary Effluent

= 5 days x 2,000 lbs/day

= 10,000 lbs.

Step (5): Therefore, the proper amount of MLSS to be wasted

= 12,700 lbs. - 10,000 lbs. = 2,700 lbs.

Step (6): Waste activated sludge pumping rate =

$$\frac{\text{Amount of solids to be wasted (lbs) in a 24-hour period}}{\text{Return sludge concentration (mg/l)} \times 8.34 \frac{\text{lbs/MG}}{\text{mg/l}}}$$

$$= \frac{2{,}700 \text{ lbs/day}}{5{,}600 \text{ mg/l} \times 8.34 \frac{\text{lbs/MG}}{\text{mg/l}}} = 0.058 \text{ MGD}$$

$$0.058 \text{ MGD} \times 695 \frac{\text{GPM}}{\text{MGD}} = 40.5 \text{ GPM}$$

This waste activated sludge pumping rate will, therefore, change the return sludge pumping rate from 835 GPM to 794.5 GPM (835 - 40.5 GPM) .

The reason the waste activated sludge pumping rate is set for 24 hours is to eliminate any rapid changes to the sensitive biological cultures.

2. Another means of estimating the wasting rate is to use the desired MLSS concentration obtained earlier in the start-up proceedings.

Assume these results were obtained from the laboratory tests:

MLSS = 2800 mg/l
Return Sludge, Suspended Solids = 5600 mg/l
Primary Effluent, Suspended Solids = 60 mg/l
Average Daily Flow = 4 MGD
Volume of Aeration Basin = 0.55 MG
and also
Desired MLSS = 2720 mg/l plus or minus 10%

Step (1): Amount of Solids to be wasted $\frac{\text{lbs}}{\text{day}}$ =

(Laboratory MLSS - desired MLSS) x Average Daily Flow x 8.34 =

(2800 - 2720 mg/l) x 4 MGD x 8.34 = 2670 lbs/day

Step (2): Waste activated sludge pumping rate =

$$\frac{2670 \text{ lbs/day}}{5600 \text{ mg/l} \times 8.34 \frac{\text{lbs/MG}}{\text{mg/l}}} = .0571 \text{ MGD} = \underline{\underline{39.6}} \text{ GPM}$$

Therefore, the return sludge pumping rate will be 795.4 GPM (835 - 39.6 GPM).

The waste activated sludge pumping rate and the return sludge pumping rate may have to be adjusted if the characteristics of the wastewater change thus changing the desired MLSS concentration. The waste activated sludge pumping rate will have to be increased or decreased in order to maintain an optimum value for MLSS in the aeration basin in order to provide the best possible treatment of the wastewater.

When the plant has stabilized, a good activated sludge should settle rapidly leaving a clear, odorless and stable supernatant. The floc should appear granular with sharply defined edges, be golden brown in color, and have a musty odor. However, there are some conditions that may occur during start-up that will indicate a poorly operating process. The operator should not expect immediate results from any of the control procedures that are presented. An experienced operator will be of greatest value when these problems arise in the wastewater treatment process.

During start-up an unstable effluent will probably result due to the inadequate biological treatment. Chlorination is often used to reduce health hazards on the receiving water. State and Federal regulatory agencies should be contacted to ensure that no harm will come to the wildlife or fish present in the receiving waters as a result of heavily chlorinating the plant effluent. The use of alum, ferric chloride and polymers as an aid to settling in final settling tanks will help reduce the BOD_5 loading on the receiving waters. The coagulants should be thoroughly mixed with the aeration basin contents before being released to the final settling tank.

During start-up, when the MLSS are low, the aeration basins may experience severe foaming. Foaming is believed to occur because of synthetic detergents and other surfactants in conjunction with high aeration and low aeration MLSS. The foam contains sludge solids, grease, and bacteria and should be brought under control as quickly as possible. Water nozzles using screened sewage or domestic water have been used successfully to control foaming. Defoaming agents are also used or possibly used in conjunction with water nozzles to help control the foaming. The operator may be able to reduce the aeration rate while maintaining his DO and building up his MLSS to aid in the control of foaming. The foaming should decrease as the MLSS continues to increase in the aeration basin and the process approaches stability.

Sludge bulking may occur during start-up due to overloading the basin. Sludge bulking is indicated by a poorly settling sludge and poor sludge compaction. The sludge blanket in the final clarifier becomes deeper and rises to overflow the weirs. The sludge settleability decreases as indicated by a significant rise in the SVI and the sludge appears light and fluffy. Sludge bulking is associated with the growth of filamentous organisms that attach themselves from one floc to another and prevent compaction of the sludge particles and poor settling results. Another cause of sludge bulking is bound water in which the bacteria, composing the floc, swell because of the addition of water and thereby decrease in density.

When sludge bulking occurs, it is usually associated with low pH, low DO, low nitrogen concentration, high F/M, industrial waste, or septic sewage. The primary purpose of control is to increase the sludge age or decrease the F/M ratio.

Low DO - The DO should be checked initially to see that at least 2 mg/l of DO exist in the aeration basin; if not, then inspect the aerating equipment to see that it is functioning correctly and increase the aeration rate. If the aerators or blowers are operating at capacity, then additional aerators, diffusers, or blowers may have to be added. The design of the aeration rate should be investigated if aerators have to be added.

Low pH - Lime is usually added, often with flocculent aids, to raise the pH and control bulking by improving the settling characteristics of the sludge while corrective action is being taken.

High F/M (Low Sludge Age) - To reduce the F/M, the organic load (F) on the basin is decreased by reducing the influent flow to the basin or the MLSS (M) is increased by increasing the return sludge rate and decreasing the wasting rate. Both of these actions should increase the sludge age.

The plant records should be reviewed in order to determine what caused the problem and in order that future operations can take measures to prevent the same conditions from occurring again.

Rising sludge should not be confused with sludge bulking. In a rising sludge, the settling characteristics and compaction are good. Rising sludge occurs as a result of too long a detention time in the clarifier. The sludge rises in chunks from the size of a pea to as large as a basketball, usually forming a brown, fine scum or froth on the surface of the settling tank. The sludge undergoes denitrification with the release of nitrogen gas that becomes entrapped in the sludge causing it to rise to the surface. By increasing the rate of return of activated sludge pumping or increasing the sludge wasting rate and decreasing the sludge age, the problem of rising sludge should be corrected.

If the start-up of the activated sludge process is in winter, it will take longer to build up the mixed liquor suspended solids which may produce strain on other operations of the plant. In winter, the loading and air rates change. The sewage will require less air and more solids to bring about efficient treatment. Usually the ambient temperature is not significant unless it raises or lowers the temperature of the liquor more than 10^{o} F.

The operator should use caution when changing the mode of operation of this process or any other. An extreme change or allowing the process to go too far the other way can be just as detrimental to treatment efficiency as the existing problem. Therefore, make any changes gradually and in an orderly step-by-step fashion.

ACTIVATED SLUDGE CHECKLIST*

To supplement the preceding recommendations for starting up an activated sludge process, the following checklist has been provided:

I. Literature Review

   A. Manufacturer's Literature

   B. Facility's Operation and Maintenance Manual

*It is assumed that the previous sections' recommendations concerning Preparation for Start-Up and Start-Up of the Pretreatment, Primary Treatment and Chlorination Facilities have been followed and an outline of start-up procedures has been made.

C. "Operation of Wastewater Treatment Plants," Environmental Protection Agency, Technical Training Grant No. 5TT1-WP-16-03

D. *WPCF Manual of Practice No. 11*, "Operation of Wastewater Treatment Plants," 1966

II. Preparation for Start-Up

A. Meet with consulting engineers and start-up experts.

1. Obtain design parameter values.

a. Flow into aeration basin

b. BOD_5 loading and concentration

c. Temperature

d. Volume of basin(s) (total and individual)

e. MLSS

f. Sludge pump capability (return and wasting pumps)

2. Determine COD to BOD_5 relationship.

a. Run BOD_5 and COD tests for at least a week prior to start-up.

b. Calculate COD to BOD_5 ratio.

B. Estimate actual start-up conditions.

1. Flow into aeration basin(s) being started

2. BOD_5 loading and concentration

3. Temperature

4. Volume of basin(s) to be started

C. Calculate "minimum" MLSS concentration for start-up.

III. Start-Up Procedure

A. With seed sludge

1. Turn aerators on and maintain a minimum DO residual of 2 mg/l.

2. Fill the aeration basin(s) with raw sewage or water.

3. Add seed sludge to bring MLSS of basin(s) being started to at least 500 mg/l.

4. Let flow into aeration basin(s) at approximately 10% of the design and increment at 10% a day.

5. Return all activated sludge from the final settling tank.

B. Without seed sludge

1. Turn aerators on and maintain a minimum DO residual of 2 mg/l.

2. Fill basin(s) with raw sewage.

3. Let flow into aeration basin.

4. Bypass flow for eight hours and aerate mixture in the basin for seven hours.

5. Turn off aerators and allow the mixture to settle for thirty to sixty minutes.

6. Again let flow into the aeration basin, bypass flow for eight hours, reaerate mixture and allow it to settle; continue until the MLSS is at least 500 mg/l.

7. Let basin accept continuous flow.

8. Return all activated sludge from the final settling tank.

IV. Process Monitoring During Start-Up

A. Measure operational control and effluent standard parameters to include:

1. MLSS in the aeration basins

2. DO in the aeration basins

3. Influent and effluent BOD_5 and COD

4. SS in the secondary clarifier

5. SVI in the secondary clarifier

6. Calculate F/M

B. Calculate return activated sludge pumping rate when aeration basin MLSS concentration reaches "minimum" MLSS concentration.

C. Permit sludge blanket to form in final settling tank to approximately one foot of depth.

D. Calculate activated sludge wasting rate and begin wasting activated sludge.

V. Normal Operation

A. Continue monitoring process by measuring the operational control and effluent standard parameters to include:

1. Influent and effluent BOD_5 concentration

2. MLSS in the aeration basin

3. SS in the secondary clarifier

4. SVI in the secondary clarifier

5. DO in the aeration basin

6. Calculate F/M

B. Adjust process

1. Return sludge rate

2. Wasting Rate

3. Air Supply

References for Additional Information:

1. "Operation of Wastewater Treatment Plants," Environmental Protection Agency, Technical Training Grant No. 5TT1-WP-16-03, Chapter 7.

2. *WPCF Manual of Practice No. 11*, "Operation of Wastewater Treatment Plants," 1966, pages 108-122.

3. *Wastewater Engineering*, Metcalf and Eddy, McGraw-Hill Book Company, Inc., New York, 1972, pages 482-533.

4. McKinney, Ross E., *Microbiology for Sanitary Engineers*, McGraw-Hill Book Company, Inc., New York, 1962 pages 213-237.

5. *Standard Methods for the Examination of Water and Wastewater*, 13th Edition, APHA, AWWA, WPCF, 1971.

TRICKLING FILTERS

The biological process involved in the trickling filter is essentially the same as with the activated sludge. In general, the trickling filter removes the dissolved and finely divided organic solids from sewage and biologically oxidizes the solids to a more stable material. The

filter media, consisting of rock, redwood slats or synthetic material, provides surface area for the development of slime growths or zoogloeal mass, containing bacteria, protozoa, algae, fungi, worms, and insect larvae. As the effluent from the primary clarifiers passes through the filter, the gelatinous growth retains much of the suspended, colloidal, and dissolved material contained in the sewage. The material is utilized as food by the organisms, thereby reducing the organic concentration of the sewage. The excess film that accumulates from the growth of new organisms is periodically or continually sloughed from the filter and separated in the final settling tanks. In this manner, a large portion of the BOD_5 loading is removed from the wastewater.

During start-up, the objective is to build up this slime growth so that the desired removal efficiency can commence as soon as possible.

Trickling filters may be classified as either standard rate (low rate) or high rate. The standard rate filter accepts loadings of 25-100 gpd/sq ft of surface area and 5-25 lbs BOD_5/day/1000 cu ft of media. This type filter usually is six to eight feet deep and rectangular or circular in shape. It is dosed intermittently by automatic or periodic pumping from the dosing tanks. The dosing rates are sufficient to keep the filter media from drying out.

The material sloughed or washed from the filter media is stable, easily settled, humus-like material, often containing worms, snails, and insect larvae. The effluent from the final settling tank usually has a BOD_5 on the order of 20-25 mg/l.

The high rate filter usually has loadings of 100-1000 gpd/sq ft of surface area and 25-300 lbs BOD_5/day/1000 cu ft of media. The high rate filter is normally three to eight feet deep and rectangular or circular in shape. This type filter has a continuous loading due to recirculation of the filter effluent. Because of the high loadings, sloughings are more frequent; therefore, the sloughed material is less stable, lighter and more difficult to settle than the standard rate filter. The BOD_5 in the effluent of the final settling tank is commonly in the range of 20-50 mg/l.

If a high rate filter has a loading greater than 300 lbs BOD_5/day/1000 cu ft of media, it is termed a roughing filter or intermediate filter due to the lower efficiency of BOD_5 removal (50 to 70 percent). This is usually used when high organics loadings are expected and little treatment is needed at this stage.

Inspection and Pretesting

A responsible person should ensure that:

1. All debris is removed from the underdrain system and basins.
2. All valves and gates have been opened and closed and inspected for proper seating.
3. The orifice openings are as specified.
4. The proper lubricant has been used and recorded for future reference.
5. All exposed metal is protected.

After assuring that this has been done, the arm of the filter (if it is a rotating type of filter) should be rotated by hand and inspected for vibration or roughness. If possible, the filter should then be loaded hydraulically and the rotation inspected and the orifice openings and flow checked.

If the filter is a fixed nozzle type, after the inspection, hydraulically load the filter and check the nozzles for clogging from debris left from construction and inspect the spray pattern to see that the media is being wetted properly.

The inspection and pretesting of the final settling tank is similar to the inspection and pretesting of the settling tank in Chapter III (Start-Up of the Pretreatment, Primary Treatment and Chlorination Facilities).

Start-Up Procedure

After pretesting the filter, start the wastewater flow to the distributor arms, observing the rotation of the arms to see that they are operating smoothly and that the waste is distributed evenly over the filter media. The revolutions per minute should be logged. If the filter is a fixed nozzle system, after inspection, start the wastewater flow to the nozzles. Inspect the spray pattern to see that the waste is distributed evenly over the filter media. Debris will clog some of the nozzles, and it is important that the nozzles be cleaned as soon as possible.

In a high rate filter, the recirculation of the final clarifier effluent helps to prevent odors and ponding of the filter by flushing the media, reducing the detention time, and keeping a

constant load on the filter. If a standard filter is being started up, it is important that the filter media be kept as wet as possible. Although a siphon is present to dose the standard filter, during start-up the flow into the plant may be such that the time interval involved with an automatic siphon will be so long that the filter will dry out. Some means of recirculation such as the use of a portable pump should be provided to make sure that the filter will remain wet and to add recirculated final clarifier effluent to the filter. Recirculation of the high rate and standard rate filter (if possible) should reduce the time required for growth to develop on the filter media.

It will take several days for growth to develop on the media, depending on the time of year, weather conditions, and the character and strength of the wastewater. During this time, a poor effluent may result. Chlorinaion and coagulants are often used to reduce the pollutional load and the health hazard on the receiving waters. Caution should be exercised when using heavy chlorination in order that no harm will come to any wildlife or fish present in the receiving waters by a large chlorine loading.

The usual control tests performed on the influent and effluent are BOD_5 or COD, suspended solids, and total solids. These tests will indicate the removal efficiency through the filter and settling tank; pH and DO tests should also be run to help indicate the condition of the filter.

The start-up and operation of the trickling filter is one of the most trouble-free types of secondary treatment. During start-up, most of the problems that may plague trickling filters such as ponding, odors, and psychoda flies will not occur. If cold weather is present, it will inhibit biological growth to some degree and, therefore, it may take longer for slime growth to develop on the filter. Cold weather is usually not a problem, but occasionally the filter will freeze, especially the standard rate which has intermittent operation. Operate the high rate filters, if possible, in parallel with little or no recirculation. Standard rate filters should be operated on a continuous loading if at all possible. This procedure will decrease the time the wastewater in the filter is exposed to the cold temperature. The orifices or sprays should be adjusted to reduce the spray effect. The erection of wind screens has also been used successfully to help reduce the problem of freezing. The filter should not be stopped unless there is danger to the mechanical facilities. The dosing tank should also be covered to reduce the effects of freezing. If the supports on a rotary nozzle were adjusted during warm weather, they will have to be readjusted due to the temperature effects on the expansion and contraction of the support wires or rods.

References for Additional Information

1. "Operation of Wastewater Treatment Plants," Environmental Protection Agency, Technical Training Grant No. 5TT1-WP-16-03, Chapter 6.

2. *WPCF Manual of Practice No. 11*, "Operation of Wastewater Treatment Plants," 1966, pages 98-107.

3. Steel, Ernest W., *Water Supply and Sewerage*, McGraw-Hill Book Company, Inc., New York, 1960, pages 522-546.

4. McKinney, Ross E., *Microbiology for Sanitary Engineers*, McGraw-Hill Book Company, Inc., New York, 1962, pages 199-212.

STABILIZATION PONDS AND AERATED LAGOONS

A stabilization pond, or oxidation pond, in general, is a shallow body of water contained in an earth basin, designed for the purpose of treating wastewater. Stabilization ponds are used as complete treatment process, or as secondary treatment for settled sewage, or as polishing for secondary effluents. The ponds are most commonly used for secondary treatment and are classified into three groups: aerobic, anaerobic, and facultative (aerobic and anaerobic).

1. An aerobic pond primarily contains algae and bacteria in suspension, and aerobic conditions prevail throughout its depth. One type of aerobic pond depends upon the algae to provide sufficient oxygen to satisfy the BOD_5 loading applied to the pond. This type of aerobic pond is usually 6 to 18 inches in depth to provide conditions suitable for algae growth. This type of aerobic pond is normally used only in small communities because of the land area required.

   A second type of aerobic pond employs mechanical aeration or air diffusers to supply most of the oxygen required. This pond has a depth of three to six feet. Both types of aerobic ponds have additional oxygen transferred to the liquid through surface aeration.

   Stabilization of the organic matter in aerobic ponds occurs in two steps. First, the carbonaceous matter in sewage is broken down by the aerobic organisms with the formation of carbon dioxide. This carbon dioxide is used by the algae during photosynthesis with the liberation of oxygen. As a result, some of the organic carbon in the

sewage is converted into algal cells which supply the sewage with additional oxygen to support further aerobic decomposition. It is important that the algae and microbial flocs be separated from the pond effluent to minimize the pollutional loading on the receiving waters. The removal of these flocs is usually accomplished in secondary settling tanks.

Aerated lagoons are similar to the aerobic pond, except the algae growth is replaced by mechanical aerators or diffusers and the lagoon is usually 6 to 12 feet deep. Although the mixing caused by aeration keeps most of the lagoon contents in suspension, usually some solids settle and undergo anaerobic decomposition. Therefore, the aerated lagoon may be further classified not only as aerobic but also facultative (aerobic and anaerobic) which is similar to the facultative stabilization pond with the mechanical aerators or air diffusers replacing the algae growth as the primary source of oxygen for the bacteria.

2. The anaerobic stabilization pond is loaded to such an extent that anaerobic conditions exist throughout most of the liquid volume. Depths up to 20 feet have been used with this type of pond. Stabilization is brought about by the anaerobic decomposition of the organic solids to organic acids, cell tissues, carbon dioxide, methane and other gaseous end products similar to an anaerobic digester without external heat.

3. The facultative pond is a combination of the two stabilization ponds mentioned previously. It is the most common stabilization pond and ranges in depth from two to six feet. The pond consists of an aerobic top layer and anaerobic bottom layer. Stabilization comes about through the aerobic decomposition of the top layer and anaerobic decomposition of the bottom layer. The top layer, referred to as the aerobic layer, requires an oxygen source such as surface mechanical aerators or an algal growth. The maintenance of the aerobic top layer minimizes the odor problem associated with the anaerobic pond.

Inspection and Pretesting

The earth levees of the pond should be inspected for seepage, erosion, soil sterilization and weedicide. The grass cover and type of grass used should be inspected by the supervisor to see it meets all regulatory agency requirements. If mechanical aerators are being used, the supervisor should see that they are installed, lubricated, and inspected according to the manufacturer's instructions. Air diffuser systems should be inspected to see if all areas of the lagoon are receiving equivalent amounts of oxygen. This can be done visually and with DO tests. The air blower and motors should be inspected for installation, lubrication, noise and vibration, clearances, and alignments.

Start-Up

Since the facultative pond is the most common type of stabilization pond, the start-up procedure will deal with this type of pond, with algae as the primary source of oxygen.

If possible, start up the pond in the warmer part of the year. Generally, the warmer the contents of the pond, the more efficient the treatment. At least one to two feet of water should be in the pond before waste is introduced in order to reduce the possibility of offensive odors and aquatic weed growth during the initial operation.

Algal blooms will usually appear in seven to twelve days after waste is introduced. A definite green color of the pond's contents is evidence of a flourishing algae population. Anaerobic decomposition of the bottom sludge causes bubbles to come to the surface near the inlet point of the pond.

Waste should be introduced intermittently to the pond during the initial start-up so that the pond does not become overloaded. The pH should be monitored and be kept above 7.5, if possible. A high pH is essential to encourage a balanced anaerobic decomposition of the bottom sludge. It also indicates high algae activity, since the algae removes the carbon dioxide from the liquid during metabolism which tends to keep the pH high.

Dissolved Oxygen (DO) tests are also run on the pond contents. The values of DO and pH should be recorded to help evaluate the condition of the pond. The operator should seek to correlate his visual observations with control tests to better maintain and operate the pond.

The pond levees should have been seeded before start-up and inspected for any damage due to boring animals. Typical problems with ponds such as scum or odors should not occur during start-up. Weeds may occur during the start-up period and should be removed as quickly as possible. Weeds can hinder circulation and provide areas for mosquito breeding

and, if not removed, will quickly multiply. Little trouble can be expected from insects if weeds or other plant growths are removed. Other minute animals that may hinder the pond operation can best be handled with approved insecticides or other chemicals. Caution should always be exercised when using chemicals around the pond because they may be harmful to the operation of the pond. Another problem that may occur during start-up is freezing. Mixing the contents and windbreaks have been used to reduce the problem of freezing.

References for Additional Information

1. "Operation of Wastewater Treatment Plants," Environmental Protection Agency, Technical Training Grant No. 5TT1-WP-16-03, Chapter 9.

2. *Manual of Wastewater Operations*, Texas Water Utilities Association, Lancaster Press, Inc., Lancaster, Pennsylvania, 1971, pages 283-301.

3. *Wastewater Engineering*, Metcalf and Eddy, Inc., McGraw-Hill Book Company, Inc., New York, 1972, pages 551-569.

SECTION V
START-UP OF THE SLUDGE HANDLING FACILITIES

One of the major objectives of wastewater treatment is solids removal. The handling of this sludge can be the most time-consuming and expensive operation in the wastewater treatment plant. Proper start-up of the sludge handling facilities will ensure that efficient treatment and disposal of the sludge is accomplished.

This section provides considerations for starting up the more common chemical conditioning and sludge dewatering units, and considerations and techniques for starting up an anaerobic digester. The guidance is general enough to apply to any type or size of unit and any size of anaerobic digester. The guidance involved with the units is not intended to duplicate or replace the individual equipment manufacturer's instructions and recommendations. The equipment manufacturer's recommendations and instructions should always be consulted whenever installing, inspecting, pretesting, lubricating, and maintaining his equipment. It is assumed that the previous sections' considerations on preparing for start-up; start-up of the pretreatment, primary treatment, and chlorination facilities; and start-up of the secondary facilities have been incorporated into the start-up procedures.

Common operating problems and their solutions not discussed in this manual can be found in the EPA's "Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants," Contract No. 68-01-0107, and the WPCF's MOP No. 11, "Operation of Wastewater Treatment Plants." Each plant's O & M Manual should also contain valuable information to help solve operating problems.

ANAEROBIC DIGESTION

In the anaerobic sludge digester, bacteria decompose the organic solids in the absence of dissolved oxygen. The organisms break down the complex molecular structure of the solids, setting free the "bound" water (water that will not separate from the sludge solids) and obtain molecular oxygen and food for their growth. Anaerobic digestion reduces the wastewater solids to a mixture that is relatively odor-free, readily dewaterable, and capable of being disposed of without causing a nuisance.

In the digestion process, organic solids are liquefied, the solids volume is reduced, and methane gas is produced by the sequential action of two different groups of bacteria living together in the same environment. One group consists of saprophytic organisms, commonly

referred to as the "acid formers." In the liquefaction step, the saprophytic bacteria attached to the sludge particles secrete extracellular enzymes which in turn liquefy and hydrolize the complex molecules of the solids into simpler compounds and give off end products, primarily organic acids. The second group of organisms, which utilize the organic acids produced by the saprophytic bateria, are the "methane formers." The organic acids (mainly acetic, propionic, and butyric) produced in the first step are acted on by the "methane formers" which secrete intracellular enzymes that break down the organic acids and form the methane and carbon dioxide gas characteristic of the anaerobic digestion process. The methane formers are not as abundant in raw wastewater as the acid formers and require an optimum pH range of 6.5 to 7.5 .

Anaerobic digesters are classified according to their loading rates and not their reaction rates since the rate of biological activity is fixed. They are usually operated at a temperature of 90^{o} - 95^{o} F. provided by heating coils inside the digester tank walls or by external heat exchangers. The low rate, conventional or standard rate digester has a loading of 0.04 to 0.07 lbs. of volatile solids/day/cubic foot of digester volume and has an average detention time of 39 days. The low rate digester uses a single tank and has an active zone where anaerobic decomposition takes place and a quiescent zone above which solids separation takes place.

The most common conventional digester is the two-stage digester and consists of two separate tanks. In the first tank, digestion occurs and the sludge is withdrawn to a second tank, usually unheated, where the sludge undergoes solids separation and sludge compaction. The second tank also provides seed sludge in the event the first tank develops operating problems. The high rate digestion process is similar to the two-stage digester of the conventional process except the loadings are greater, usually 0.15 to 0.4 lbs. of volatile solids/day/ cubic foot of digester volume with an average detention time of fifteen (15) days. Mixing and digestion occur in the first tank and the sludge is then removed to a second tank where solids separation and sludge concentration take place under quiescent conditions.

The object of start-up of any anaerobic digestion process is to provide a suitable environment for the bacteria to prosper by controlling food suppiy, volatile acid concentration, total alkalinity concentration, mixing, temperature and pH. During start-up of an anaerobic digester, using no seed sludge or chemicals and with no upsets, digestion should proceed similar to the plot of Figure No. 3. (Summary plot of data observed during batch digestion studies)

Figure No. 3 shows that the volatile acid production, methane production, and alkalinity are not stable for a number of days after start-up begins. The use of seed sludge during start-up

places initial start-up on the right side of the graph where the above parameters are more stable. Therefore, the best means of starting a digester is with the aid of a well-digested stable seed sludge.

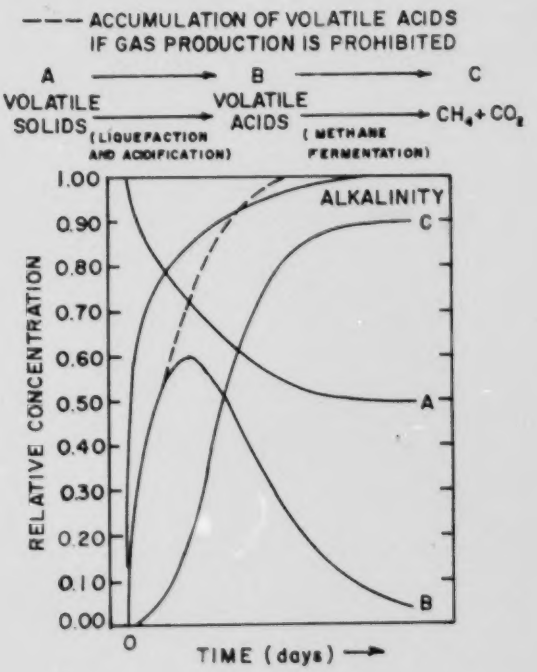


FIGURE NO. 3
SEQUENTIAL MECHANISM OF ANAEROBIC SLUDGE DIGESTION

(Courtesy of Texas Water Utilities Association "Manual of Wastewater Operations" Fig. 18-2)

Inspection and Pretesting

The inspection and pretesting of the sludge digester is complex and involves pumping the sludge, mixing the sludge, withdrawing the sludge, and withdrawing the gas and liquid. Because anaerobic digestion involves biological active cultures and explosive gases, start-up is no time to have the gas withdrawal system, heat exchanger, sludge pump, or mixer break down due to an oversight in inspecting and testing the equipment.

Again, it is stressed that the plant supervisor should observe construction of the digester and installation of all piping, valves, and equipment to ensure that it is installed according to the manufacturer's recommendations and instructions.

In general, the supervisor should see that:

1. All debris from the piping and tank is removed.

2. All valves are inspected for proper and smooth operation, and the seating checked.

3. The safety devices such as flame traps and pressure release valves are checked for proper operation.

4. The sludge pumps are free of debris, properly lubricated, no undue vibration or noise, and the drive alignments are correct.

5. The heat exchanger (if the plant is so equipped) is inspected to ensure all water, sludge, and heating connections are correct and no leaks are present.

6. All gages are inspected and calibrated.

7. The mixers are operating satisfactorily, properly lubricated and mounted securely.

There should also be some means available to mix a lime slurry and add it to the digester contents. The equipment should be inspected to see that they will operate properly and the required chemicals are on hand prior to start-up.

Start-Up Procedure

The start-up of the anaerobic digestion process can be accomplished by using seed sludge or raw waste-water to begin the biological decomposition of the sludge:

1. The first step in starting up any anaerobic digestion process using seed sludge is to estimate the proper quantity of seed sludge based upon the initial digester loading. If the volume of seed sludge available is limited, it may be necessary to estimate the digester loading

based upon the available seed sludge. Example 5 contains sample calculations for estimating the volume of seed sludge based upon the initial loading. If the calculated volume of seed sludge is too large or otherwise prohibited, the procedures in Example 5 can be reversed to obtain an estimated digester loading rate for a known volume of seed sludge. This procedure permits the seed sludge to digest only a portion of the total sludge feed and uses only a portion of the digester volume until the digester can be filled with digesting sludge. However, when starting a digester without using full sludge flow, provisions for disposing of the remainder of the feed sludge will have to be made.

EXAMPLE 5: SEED SLUDGE ESTIMATION (Primary sludge as feed)

Assume these sewage characteristics exist in the primary clarifier(s) at start-up:

Influent, Suspended Solids = 250 mg/l
Effluent, Suspended Solids = 150 mg/l
Influent Flow = 10 MGD ≈ Effluent Flow

(1) Calculate lbs. of sludge accumulated in clarifier(s)

$$\text{lbs. in Influent} = 10 \text{ MGD} \times 250 \text{ mg/l} \times 8.34 \frac{\text{lbs/MG}}{\text{mg/l}}$$

$$= 20,800 \text{ lbs.}$$

$$\text{lbs. in Effluent} = 10 \text{ MGD} \times 150 \text{ mg/l} \times 8.34 \frac{\text{lbs/MG}}{\text{mg/l}}$$

$$= 12,500 \text{ lbs.}$$

lbs. accumulated in one day = 20,000 - 12,500 lbs.

= 8,300 lbs. of sludge to be pumped to the digester.

(2) Assume that the seed sludge and primary clarifier have been analyzed and these results obtained:

Primary Clarifier Sludge = 5% total solids (TS) with 70% volatile solids (VS)

Seed Sludge = 10% total solids (TS) with 60% volatile solids (VS) at 9 lbs/gal

Estimate the amount of sludge to be pumped to the digester per day (1% solids = 10,000 mg/l)

$$MGD = \frac{\text{lbs. of sludge to be removed to digester}}{\text{consistency of sludge} \times 8.34 \frac{\text{lbs/MG}}{\text{mg/l}}}$$

$$= \frac{8,300 \text{ lbs/day}}{5\% \times 8.34 \frac{\text{lbs/MG}}{\text{mg/l}}} = \frac{8,300 \text{ lbs/day}}{50,000 \text{ mg/l} \times 8.34 \frac{\text{lbs/MG}}{\text{mg/l}}}$$

$$= 0.0199 \text{ MGD}$$

$$= \underline{\underline{19,900}} \text{ GPD}$$

The pumping time can be determined based upon the pump capabilities of the plant.

For instance, if the plant has a combined pumping capability for sludge removal of 100 GPM, then the time of pumping equals:

$$\frac{\text{19,900 gallons of sludge to be removed per day}}{\text{100 gallons per minute}}$$

$$= \underline{\underline{199}} \text{ minutes of pumping time per day}$$

This time should be divided through as long a period of time as practical in order to provide as continuous a feeding of sludge as possible to the digester, in this case possibly one hour and six minutes for each shift.

(3) Determine lbs/day of volatile solids pumped to the digester:

lbs/day of volatile solids = (Volume or rate of sludge, GPD) x (% sludge solids expressed as decimal equivalent) x (% volatile solids expressed as decimal equivalent) x (8.34 lbs/gal)

= (19,900 GPD) x (.05) x (.7) x (8.34 lbs/gal)

= 5,808 lbs/day

(4) The design engineer should be called upon to aid in selecting a suitable volatile solids loading ratio.

Normal loading rates undergoing active digestion are 0.03 - 0.10 lbs. VS/day/lbs of VS undergoing digestion. These values are based upon the design loading rate of the digester, and the design engineer should be of help in selecting volatile solids loading rate.

For this example assume: $\frac{0.05 \text{ lbs. VS/day}}{1 \text{ lb. VS undergoing digestion}}$

(5) Estimate the amount of seed sludge needed to treat the loading at 5,808 lbs/day from the clarifier.

$$\frac{0.05 \text{ lbs. VS/day}}{1 \text{ lb. VS undergoing digestion}} = \frac{5,808 \text{ lbs/day}}{\text{Weight of seed sludge VS}}$$

By rearranging terms

$$\frac{5,808}{0.05} \text{ lbs. of VS of seed sludge} = 116,200 \text{ lbs. of VS}$$

Therefore

$$\frac{116,200 \text{ lbs. VS}}{(\% \text{ TS of Seed}) \times (\% \text{ VS of Seed}) \times \text{Density of Seed Sludge}}$$

$$= \frac{116,200 \text{ lbs. VS}}{(.1) \times (.60) \times 9 \text{ lbs/gal}}$$

= 215,185 gals. of Seed Sludge

Fill the digester with the calculated or available volume of seed sludge and the remaining volume with raw sewage until the liquid flows over the maximum overflow pipe or until the floating cover lifts 12 inches off the corbels. Heat the contents 90-95° F. and

maintain within plus or minus 1^{o} F. Since the methane bacteria are upset relatively easily by rapid temperature variations, the temperature should be maintained above 90^{o} F. and any change in digestion temperature should be brought about gradually. After the temperature is stabilized, begin adding the raw sludge at a rate no greater than the predetermined rate to the digester and circulate and mix the contents. If a gas mixing device is used, the gas mixer will be inoperative until gas production occurs and the circulation system on the heat exchanger will have to be used for mixing. Mixing is important because it provides intimate contact between the seed organisms and the raw sludge and distributes the heat evenly throughout the sludge mass. Feeding from the clarifier or thickener should be well-controlled to provide a sludge of at least four percent solids content and to provide as continuous a feeding as possible. This usually results in almost immediate start-up of the digestion process. The initial feeding rate may have to be reduced because of the amount of seed sludge present in order not to overload the seed sludge. (See Example 5.)

On the second day of start-up, begin determining the control parameter values. The volatile acids test takes two - three hours, the alkalinity test (15 minutes), pH test (five minutes), gas analysis (30 minutes), and the volatile solids test (one hour), assuming the operator, lab technician, or chemist has experience in running the tests. The volatile acids, alkalinity, pH and gas analysis should be determined three times a day and volatile solids daily, assuming digestion is proceeding without any problems, in which case the tests should be run more often. The values of the control parameters may not change greatly in an eight-hour period, but the values obtained from each shift will give a means of confirming any previous control action taken.

Initially, the alkalinity and pH may decrease but should stabilize in four or five days as the methane formers begin to reproduce. However, the methane formers have a lower rate of reproduction than the "acid formers," and if the feed rate is too high, the process may fail because the excess volatile solids produced will inhibit the methane producing organisms. If the volatile acids begin to increase

beyond twice the buffering alkalinity capacity of the digester, gas production is decreasing, and the pH is decreasing, seed sludge should be added from another digester or the second stage digester and the sludge feeding rate should be decreased. If these controls are not available, add chemicals for buffering alkalinity as required. It is important to maintain a suitable environment in the digester for the methane formers, that is, a pH of 7.0 to 7.5, alkalinity approximately twice that of the volatile acids, and a temperature of 90-95° F. The amount of buffering alkalinity to be added can be determined by taking a sample from the digester and adding the buffering alkalinity until the sludge has a neutral pH (7.0) and then adding a proportionate amount, in a slurry, to the digester contents. It is essential when adding chemical aids to provide adequate mixing in the digester. The operator, chemist, or lab technician should exercise caution when adding buffering alkalinity to a digester to neutralize excess volatile acids and raise the pH. The buffering alkalinity added may cause the concentration of any cations present to reach toxic or inhibitory levels. (See Table 2.)

Cation	Concentrations (mg/l)	
	Moderately Inhibitory	Strongly Inhibitory
Calcium (Lime)	3500 - 5500	8000
Sodium	2500 - 4500	12000
Potassium	2500 - 4500	8000
Magnesium	1000 - 1500	3000

TABLE 2
INHIBITORY CONCENTRATIONS OF ALKALI AND ALKALINE-EARTH CATIONS
(McCarty, P. L., and McKinney, R. E., *Journal WPCF*, April, 1961)

With the use of seed sludge for start-up, the gas analysis and volatile solids test is a good measure of the digestion process. The CO_2 and CH_4 (carbon dioxide and methane) ratio and the volume of volatile

solids destroyed should not change markedly after start-up or digester upset may be indicated. An increase in volatile acid production (followed by or with a decrease in alkalinity) will precede the reduction of gas production in the digester, indicating digester upset.

2. If seed sludge is not available, fill the digester with raw sewage and heat the contents to 90-95° F. and add raw sludge mixed with the buffering alkalinity slurry to the digester.

If seed sludge is not being used for start-up, then the use of chemicals to control alkalinity and pH is recommended. On the second day of start-up, begin performing the volatile acids, alkalinity, pH, gas analysis and volatile solids test as mentioned previously. By taking the values of the volatile acids and alkalinity test, the amount of buffering alkalinity to be added can be calculated using a volatile acids-to-alkalinity ratio of 0.5. During normal digester operation, the VA/Alk should equal .3 to .4, but for start-up .5 is used as a conservative figure in order to avoid adding toxic levels of cations to the digester. The amount of buffering alkalinity to be added should be adjusted after each of the tests or during each shift since the volatile acids and alkalinity will change quickly.

EXAMPLE 6: CHEMICAL ADDITION FOR DIGESTER CONTROL DETERMINATION

Assume these conditions exist in the digester on the 3rd day of start-up:

Volatile Acids (VA) = 1000 mg/l
Alkalinity (Alk) = 500 mg/l

The quantity of alkalinity to ensure a favorable environment for the methane bacteria =

$$\frac{\text{Volatile Acid Concentration in the sludge}}{\text{VA/Alk ratio} = 0.5} = \frac{1000 \text{ mg/l}}{0.5}$$

$$= \underline{\underline{2000}} \text{ mg/l}$$

The alkalinity quantity to be added by chemical addition:

Alkalinity quantity for the methane bacteria - Alkalinity in the sludge = 2000 mg/l - 500 mg/l = $\underline{1500}$ mg/l

If the volume of sludge in the digester is known, the weight of chemicals to be added can be determined:

Assume the volume of sludge in the digester = .224 MG:

(lbs.) chemical to be added in a slurry

= Volume of sludge in digester (MG) x alkalinity to be added (mg/l) x 8.34 $\frac{lb/MG}{mg/l}$

= .224 MG x 1500 mg/l x 8.34 $\frac{lb/MG}{mg/l}$

= 2,800 lbs. of bicarbonate alkalinity

The chemical dosage calculated above is a great deal to add to the sludge and will be expensive. However, note that in the example, on the third day of start-up, the volatile acids equal 1000 mg/l and the alkalinity is only 500 mg/l. If the digestion process is monitored closely on the second day of start-up, this amount of chemicals should not be necessary. Instead, only a small quantity should have to be added because, initially, the alkalinity should be greater than or equal to the volatile acids (see Figure No. 3) as can be seen from Example No. 6. (Note: The time of three days used in Example No. 6 is arbitrary and does not necessarily reflect the true time span under actual start-up conditions.)

When the volatile acids concentration begins to decrease (approximately seven days) and the methane production begins to increase greatly, chemical additions should be decreased. At this time, the methane formers are beginning to feed and reproduce, thereby reducing the volatile acids and producing methane gas and their own buffering alkalinity. If, after 10 to 14 days, the digestion process shows little sign of stabilizing, decrease the feed rate and stop chemical addition. Inspect the feed sludge and digester sludge for cation or industrial toxicity and monitor the control parameters to see if digestion recovers. If possible, place second stage sludge back into the primary digester to provide methane producing organisms and buffering capacity, if toxicity is not present. If, on the other hand, when raw sludge is added, the volatile acids do not rise or

decrease sharply, the alkalinity continues to rise, the pH does not drop further and the volatile solids reduction continues to increase, then progress is indicated. Gas production should be monitored and should show an increase in the methane content of the gas. Normal operation usually is established within 30-40 days, without the use of seed sludge, as indicated by a methane gas concentration of 60-70% of the digester gas composition. If foaming occurs, reduce the feed sludge loading or add well-digested sludge from another digester. If mechanical mixers are used, reverse their direction to mix the foam into the sludge mass.

ANAEROBIC DIGESTION CHECKLIST*

To supplement the preceding recommendations for starting up any Anaerobic Digestion Process, the following checklist has been provided:

I. Literature review to become familiar with the Anaerobic Digestion Process

- A. Manufacturer's literature on the digestion process equipment
- B. Facility's Operation and Maintenance Manual
- C. "Operation of Wastewater Treatment Plants," Environmental Protection Agency, Technical Training Grant No. 5TT1-WP-16-03, Chapter 8
- D. *WPCF Manual of Practice No. 11*, "Operation of Wastewater Treatment Plants," 1966, pages 39-62
- E. *WPCF Manual of Practice No. 16*, "Anaerobic Sludge Digestion," 1968

II. Preparation for Start-Up

- A. Meet with consulting engineers and start-up experts.
  - 1. Obtain design parameter values.
    - a. Volume of digester(s)

*It is assumed that the previous sections' recommendations concerning Preparation for Start-Up and Start-Up of the Pretreatment, Primary Treatment and Chlorination Facilities have been followed and an outline of start-up procedures has been made.

b. Volatile solids loading to digester(s)

c. Solids concentration of sludge pumped to digester(s)

B. Estimate actual start-up conditions.

1. Estimate volatile solids and total solids loading to digester(s).

III. Start-Up Procedure

A. Seed Sludge

1. Estimate the percent total solids and volatile solids and the density of the seed sludge.

2. Calculate the amount of seed sludge to be added based on estimated start-up loading.

3. Add seed sludge to the digester(s) and fill the remaining volume with raw sewage.

4. Heat contents of the primary digester(s) to 90-95^{o} F. and maintain within plus or minus 1^{o} F.

5. Mix contents of the primary digester(s) thoroughly and continuously.

6. Pump raw sludge to the digester(s) at the estimated solids loading rate as continuously as possible.

7. Measure the control parameters.

a. Volatile acids approximately three times a day

b. Total alkalinity approximately three times a day

c. pH approximately three times a day

d. Gas analysis for methane and carbon dioxide approximately three times a day

e. Volatile solids approximately once a day

f. Calculate VA/Alk

8. Adjust process.

a. Increase feed if volatile solids are lower than desired.

b. Decrease feed if volatile solids are greater than desired.

B. Without seed sludge

1. Fill the digester(s) with raw sewage.

2. Heat the contents of the digester to 90-95^{o} F. and maintain within plus or minus 1^{o} F.

3. Mix the contents thoroughly.

4. Pump raw sludge to the digester at 10% of design loading.

5. Measure the control parameters.

a. Volatile acids (VA) three times a day

b. Total alkalinity (Alk) three times a day

c. pH three times a day

d. Gas analysis for methane and carbon dioxide once a day

e. Volatile solids (VS) once a day

f. Calculate VA/Alk

6. Adjust process.

   a. Calculate chemical quantity to be added to digester contents.

   b. Add chemical in a slurry to the digester to maintain the pH and VA/Alk ratio favorable to the methane organisms.

   c. Reduce chemical feed as digestion process stabilizes.

   d. Increase loading by 10%.

IV. Normal Operation

   A. Monitor control parameters of pH, VA/Alk, gas analysis and volatile solids.

   B. Adjust feed until the sludge in the digester is in equilibrium.

References for Further Information

1. "Operation of Wastewater Treatment Plants," Environmental Protection Agency, Technical Training Grant No. 5TT1-WP-16-03, Chapter 8.

2. *WPCF Manual of Practice No. 11*, "Operation of Wastewater Treatment Plants," 1966.

3. *Wastewater Engineering*, Metcalf and Eddy, McGraw-Hill Book Company, Inc., 1972.

4. McKinney, Ross E., *Microbiology for Sanitary Engineers*, McGraw-Hill Book Company, Inc., 1962, Chapter 23.

5. "A Study of Sludge Handling and Disposal," U. S. Department of the Interior, Federal Water Pollution Control Administration, Publication WP-20-4, May, 1968.

6. *Standard Methods for the Examination of Water and Wastewater*, 13th Edition, APHA, AWWA, WPCF, 1971.

SLUDGE CONDITIONING

A. **THICKENING** is the process of removing water from the primary or secondary sedimentation tank sludge. The purpose of sludge thickening is to reduce the volume of the liquid sludge by increasing the concentration of the solids. This increases the solids holding capacity of the digester, reduces the heat requirement, and allows the digester generally to operate more efficiently. The increase in solids content by thickening may be as much as 100 percent. There are basically two methods for thickening sludge -- by gravity and by flotation.

The gravity thickener concentrates the sludge by resettling much like the settling tanks without mechanical rakes. Sludge removed from secondary settling tanks usually cannot be concentrated sufficiently by gravity thickening alone.

Gravity thickening with mechanical rakes increases the efficiency of the dewatering unit. Compaction occurs as a result of the compression due to the weight of the solids themselves and by the breaking up of the floc by the rakes, thereby permitting water to escape. This method is often used to handle sludge from the secondary settling tanks, due to the increase in solids concentration.

Another method used to thicken sludge is through flotation. This procedure is basically the same as described in the start-up of the flotation units. (See Section III, Start-Up of the Pretreatment, Primary Treatment, and Chlorination Facilities.) The process involves the separation of solids from sludge by applying air under pressure through the sludge mass. The flocculated sludge collects at the surface of the aerated liquid where it is removed by collecting equipment.

Inspection and Pretesting

The basin and piping should be free of all debris. The drive motors, if used, should be checked for proper rotation, drive alignment, clearances, noise, vibration, and lubrication. The weir levels should be inspected and made level. If a flotation thickener is used, the air blower should be inspected and the air lines checked for leaks. The diffusers should be inspected for any defects or clogging before installation. The manufacturer's instructions should be on hand for guidance in inspecting and pretesting the equipment.

Start-Up

After the sludge has begun to develop a blanket in the thickener, the suspended solids (SS) and sludge volume index (SVI) should be determined. The suspended solids will determine the thickener's efficiency and the SVI will aid in recognizing a bulking sludge. Sludge pumping should be stopped when the sludge appears thin. The same problems that plague settling tanks occur in thickeners. The problems of bulking sludge, rising sludge, and septicity are discussed under the Settling Tanks (Section III) of this manual. Chemical coagulants also have been used with thickeners to aid in the densification of the sludge. Sludge should be withdrawn when it consists of 4% - 8% dry solids as indicated by the total or suspended solids test or by visual observation. The laboratory tests should be performed to verify the operator's judgment and for the plant's files.

B. **ELUTRIATION** is a unit operation having the dual function of both conditioning and thickening. It is a washing process where alkalinity is removed from the digested sludge thereby reducing chemical coagulant demand used for conditioning the sludge for dewatering.

The mixing action of the sludge with water is accomplished by mechanical or diffused air agitation for a period of 1-2 minutes. The mixture of water and sludge is then settled and the sludge is removed to other dewatering processes and operations. The supernatant is returned to another plant unit, usually the primary settling tank. Because this concentration of the solids in the sludge may be increased, this process is also considered to act as a thickening unit.

This process may remove up to 80 percent of the alkalinity and reduce the amount of ferric chloride used for conditioning the sludge by as much as 65 to 80 percent.

Inspection and Pretesting

The basin and piping should be cleared of all debris and the drive motors inspected for secure mounting, rotation, drive alignment, clearances, vibration, noise, and lubrication. If an air blower is used, it should also be inspected and the air lines checked for leaks and the diffusers inspected for proper operation. The manufacturer's suggestions for inspecting and pretesting the equipment should be followed also.

Start-Up

The alkalinity of the sludge before and after elutriation should be determined. The alkalinity determination will provide a measure of the efficiency of the process by indicating the amount of alkalinity removed. This measure can be used to estimate the savings involved in reducing the amount of chemical conditioning used.

C. CHEMICAL CONDITIONING is usually used in advance of vacuum filtration or centrifugation as an aid in increasing the solids content of the sludge. Certain chemicals, alone or in combination, when added to raw or digested sludge result in the release of bound water and the formation of a relatively insoluble floc which agglomerates suspended and colloidal particles. Chemicals used have included sulfuric acid, alum, chlorinated copperas, ferrous sulfate, polymers, and, most commonly, ferric chloride, with or without lime. Lime with ferric chloride is used to reduce the alkalinity of the sludge if other means such as elutriation are not used. Lime reduces the alkalinity by precipitating the bicarbonate alkalinity of the liquid portion of the sludge, thereby reducing the amount of ferric chloride needed to condition the sludge. The chemical dosage as determined in the laboratory is usually mixed with the sludge by mechanical means for 1 to 2 minutes before the sludge is dewatered.

Inspection and Pretesting

The mixing basin and piping should be cleared of debris. The mixers should be inspected for mounting, rotation, clearances, alignment, noise, vibration, and lubrication. The mixing action should be checked to see that it is mixing through the basin. The chemical metering system should be checked for proper calibration. All recorders should be checked for proper operation.

Start-Up

The mixers and recorders should be inspected periodically during start-up to see that they are functioning correctly.

SLUDGE DEWATERING

The most common methods of dewatering raw or digested sludge are by the use of drying beds, vacuum filters and centrifuges.

A. The SLUDGE DRYING BED dewaters digested sludge through evaporation and percolation. The bed consists of an underdrain system, a course of crushed rock and gravel, and a cover of 9 to 12 inches of sand. Some drying beds have glass covers to reduce environmental effects that would conflict with the operation of the drying bed and also reduce the required area for drying beds by reducing the time required for drying.

Inspection and Pretesting

The underdrain system should be cleared of debris. The sand layer should be inspected for uniformity and raked smooth. The baffle should be placed correctly to ensure the sand is not washed out.

Start-Up

Before application of the digested sludge, the sand bed should be raked to loosen the compacted sand. The bed should be leveled and sludge admitted to a depth of approximately 12 inches.

Sludge from the digester should not be drawn too quickly, or coning may develop in the digester or the sand bed may be damaged.

The sludge is dry when large cracks appear at the surface and extend to the sand bed. The dried sludge may be removed by hand with a fine fork, shovel, or other appropriate equipment. As sludge is removed, some sand is lost and must be replaced from time to time. Mechanical equipment, trucks, or any other equipment that would damage the sand bed should not be permitted on the beds, unless the design and construction of the beds provide for this contingency.

B. VACUUM FILTRATION is a unit operation that usually requires the addition of chemicals to assist in dewatering the raw or digested sludge. After the chemical addition and mixing (to aid coagulation by the release of bound water), the sludge is ready to be withdrawn to the vacuum filter.

Although there are a number of different types, the more common filter is a cylindrical drum with some filter media covering the outside surface. Internally the drum is divided into drainage compartments which connect to the filtrate system. Approximately 20 to 40 percent of the drum is

submerged in the filter "pan" which contains the sludge. The sludge mat is formed on the filter surface as a result of a vacuum applied to the drainage compartments that are in the submerged portion. As the mat rotates out of the "pan," vacuum and dewatering are continuing. The cake is removed by releasing the vacuum and applying a light air pressure to the inside of the filter, lifting the cake away from the filter where, with the aid of a scraper, the cake is discharged into a hopper or onto a conveyor belt.

Some filters eliminate the scraper and air backblow by using coil springs as the filter media. The cake is discharged by the lifting action of the coils as they leave the drum and travel to a discharge roller. The cake is discharged to a hopper or conveyor belt as the coils pass around a return roller.

The vacuum filter, if operating and maintained correctly, should produce a 4 – 5 lbs/sq ft/hr of cake with a solids content of 20 to 40 percent for primary sludge, and varies with the applied solids concentration.

Inspection and Pretesting

The supervisor should be on hand when the unit is installed to see that it is done according to the manufacturer's instructions and to note any problems that arise in the instaliation of the unit. The air and/or water lines should be checked for leaks and all valves checked for smooth and proper operation. The unit should be lubricated and checked for clearances and alignment. The motors should be inspected to see that they are rotating correctly, properly lubricated, aligned and create no undue noise or vibration. The scraper should be checked for clearance and alignment. Sludge and water withdrawal system should be checked. The filter media should be carefully checked before instaliation and once again as the unit is put into operation to see it is rotating smoothly without binding.

Start-Up

As the sludge begins entering the vat, the unit should be prepared for operation. When the sludge is at the proper depth, the unit should be turned on and inspected frequently for proper operation. The total yield, moisture content, total solids, and volatile solids of the filtered sludge should be determined daily. Other tests normally performed are total solids, volatile solids, alkalinity and pH before the sludge is filtered.

C. CENTRIFUGATION separates the sludge solids from the liquid through sedimentation and centrifugal force. Chemical addition and mixing are sometimes used to render the process more effective in the dewatering of the sludge.

Centrifuges are various sized cylinders that rotate at high speeds. The sludge is pumped to the center of the bowl where centrifugal force established by the rotating drum separates the lighter liquid from the denser solids. A screw conveyor inside the drum removes the solid portion. The liquid portion is removed at the opposite end over adjustable weirs and usually returned to the thickener or primary clarifier. If operated and maintained correctly, the centrifuge should procuce a cake of 30 to 35 percent solids.

Inspection and Pretesting

The installation of the centrifuge should be checked to ensure it has been done in accordance with the manufacturer's instructions and specifications. The alignment of the unit's drum and screw conveyor should be inspected for proper clearances. The drive motor and coupling should be checked for proper alignment. See that the unit is properly lubricated and the lubricant recorded. Check the sound and vibration dumping to see that it is installed correctly.

Jog the mechanism through one revolution listening for any unusual noise and look for any undue vibration. Check clearances, drive alignment, and rotation.

Start-Up

As waste begins entering the bowl, inspect the mechanism once again for proper operation. Run tests on moisture and percent solids before and after centrifugation in order to determine the efficiency of the centrifuge.

DISPOSAL

The principal methods of sludge disposal are: incineration, where the sludge cake is reduced to an ash and the ash is spread on the land; lagooning, where the sludge is allowed to dewater naturally by percolation and evaporation, followed by removal of the residue by bulldozers or other appropriate methods; burial, where the sludge usually contains constituents which render other methods impractical; land fill, where the sludge, either wet or dewatered, is placed on fill and promptly covered with earth; soil conditioner, where the

sludge is spread on top of the surface for agricultural purposes; and ocean barging, where the sludge is diluted in the ocean or other large bodies of water. For further information on the subject of disposal see "A Study of Sludge Handling and Disposal," U. S. Department of the Interior, Federal Water Pollution Control Administration, Publication WP-20-4, May, 1968.

SECTION VI
APPENDICES

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ASSOCIATED EPA PROGRAMS

The Environmental Protection Agency is developing several manuals to assist in the proper operation and maintenance of municipal wastewater treatment plants. These manuals may be useful in preparing for start-up.

A Planned Maintenance Management Program, Project No. 11010 GWI

Estimating Staffing for Municipal Wastewater Treatment Facilities, Contract No. 68-01-0328

Estimating Laboratory Needs for Municipal Wastewater Treatment Facilities, Contract No. 68-01-0328

Emergency Operating Procedures for Municipal Wastewater Treatment Facilities, Contract No. 68-01-0341

Maintenance Management Systems for Municipal Wastewater Facilities, Contract No. 68-01-0341

Emergency Response Program for Municipal Wastewater Treatment Facilities - State and Local Aspects, Contract No. 68-01-0341

Middle Management Concepts for Municipal Wastewater Operations, Contract No. 68-01-0341

Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants, Contract No. 68-01-0107

Safety in the Design, Operation and Maintenance of Wastewater Treatment Works, Contract No. 68-01-0324

Design Criteria for Mechanical, Electric, and Fluid System and Component Reliability, Contract No. 68-01-0001.

Methods for Chemical Analysis of Water and Waste, GPO Stock No. 5501-0067

GLOSSARY

AEROBIC – Requiring or not destroyed by, the presence of free elemental oxygen.

AEROBIC BACTERIA – Bacteria which will live and reproduce only in an environment containing oxygen which is available for their respiration such as atmospheric oxygen or oxygen dissolved in water.

ALGAE – Primitive plants, one or many celled, usually aquatic, and capable of elaborating their foodstuffs by photosynthesis.

ALKALINITY (ALK) – The capacity of water to neutralize acids, a property imported by the water's content of carbonates, bicarbonates, hydroxides, and occasionally borates, silicates and phosphates.

ANAEROBIC – Requiring, or not destroyed by, the absence of air or free (elemental) oxygen.

ANAEROBIC BACTERIA – Bacteria which will live and reproduce in an environment containing no "free" or dissolved oxygen.

BACTERIA – A group of universally distributed, rigid, essentially unicellular microscopic organisms lacking chlorophyll.

BOD – (1) Abbreviation for biochemical oxygen demand. The quantity of oxygen used in the biochemical oxidation of organic matter in a specified time, at a specified temperature, and under specified conditions. (2) A standard test used in assessing wastewater strength.

BOUND WATER – Water strongly held on the surface of colloidal particles.

COAGULANTS – Chemicals added to destabilize, aggregate, and bind together colloids and emulsions to improve settleability, filterability, or drainability.

COD – Abbreviation for chemical oxygen demand. A measure of the oxygen-consuming capacity of inorganic and organic matter present in water or wastewater. It does not differentiate between stable and unstable organic matter and thus does not necessarily correlate with biochemical oxygen demand.

DETENTION TIME – The time required to fill a tank at a given flow or the theoretical time required for a given flow of wastewater to pass through a tank.

DO – Abbreviation for dissolved oxygen. The oxygen dissolved in water, wastewater, or other liquid.

EFFLUENT – Wastewater or other liquid which flows out of a basin, treatment process, or treatment plant.

ELUTRIATION – A process of sludge conditioning whereby the sludge is washed with either fresh water or plant effluent to reduce the demand for conditioning chemicals and to improve settling or filtering characteristics of the solids.

ENDOGENOUS – A diminished level of respiration in which materials previously stored by the cell are oxidized.

ENZYME – A catalyst produced by living cells.

FACULTATIVE BACTERIA – Bacteria which can adapt themselves to growth in the presence, as well as in the absence of, elemental oxygen.

FLOC – Groups of bacteria that have joined together to form a cluster increasing the density where it will settle.

FUNGI – Small nonchlorophyll-bearing plants which lack roots, stems, or leaves, which occur (among other places) in water, wastewater, or wastewater effluents and grow best in the absence of light.

GRIT – The heavy suspended mineral matter present in water or wastewater such as sand, gravel, and cinders.

INFLUENT – Water, wastewater, or other liquid flowing into a reservoir, basin, treatment process, or treatment plant.

INORGANIC MATTER – Chemical substances of mineral origin which may contain carbon and oxygen.

LIQUEFACTION -- Liquefaction as applied to sludge digestion means the transformation of large solid particles of sludge into either a soluble or finely dispersed state.

MEDIA -- Rocks or other material in a trickling filter over which settled wastewater is sprinkled and then flows over and around during treatment. Slime organisms grow on the surface of the media and treat the wastewater.

MESOPHILIC RANGE -- Operationally, the temperature range most conducive to the maintenance of optimum digestion by mesophilic bacteria, generally accepted as between 27^{O} and 32^{O} C (80^{O} and 90^{O} F.).

MIXED LIQUOR -- A mixture of activated sludge and organic matter undergoing activated sludge treatment in the aeration tank.

NITRIFICATION -- The biochemical conversion of unoxidized nitrogenous matter (ammonia and organic nitrogen) to oxidized nitrogen (usually nitrate).

ORGANIC MATTER -- Chemical substances of animal or vegetable origin, or more correctly, of basically carbon structure, comprising compounds consisting of hydrocarbons and their derivatives.

ORGANISMS -- A form of life composed of mutually dependent parts that maintain various vital processes.

PATHOGENIC ORGANISMS -- Bacteria or viruses which can cause disease (typhoid, cholera, dysentery).

pH -- A measure of the concentration by weight of hydrogen ions, in grams, per liter of solution. Neutral water, for example, has a pH of 7; acid water has a pH of less than 7; and alkaline water has a pH of greater than 7.

PROPORTIONAL WEIR -- A special type of weir in which the discharge through the weir is directly proportional to the head.

PROTOZOA -- Small one-celled animals.

SAPROPHYTIC -- Living on dead or decaying matter.

SETTLEABLE SOLIDS – (1) That matter in wastewater which will not stay in suspension during a preselected settling period, such as one hour, but either settles to the bottom or floats to the top. (2) In the Imhoff cone test, the volume of matter that settles to the bottom of the cone in one hour.

SLOUGHINGS – Trickling filter slimes that have been washed off the filter media.

SLUDGE – (1) The accumulated settleable solids separated from liquids, such as water or wastewater, during processing. (2) The precipitate resulting from chemical treatment, coagulation, or sedimentation of water or wastewater.

SLUDGE AGE – In the activated sludge process, a measure of the length of time a particle of suspended solids has been undergoing aeration, expressed in days.

SLUDGE BLANKET – Accumulation of sludge hydrodynamically suspended within an enclosed body of wastewater.

SLUDGE BULKING – A phenomenon that occurs in activated sludge plants where the sludge occupies excessive volumes and will not concentrate readily.

SLUDGE VOLUME INDEX (SVI) – The ratio of the volume in milliliters of sludge settled from a 1,000 ml sample in 30 minutes to the dry-weight concentration of the suspended solids in the mixed liquor in mg/l and this ratio multiplied by 1,000.

SUSPENDED SOLIDS (SS) – The quantity of material removed from wastewater in a laboratory test, as prescribed in "Standard Methods for the Examination of Water and Wastewater" and referred to as nonfilterable residue.

THERMOPHILIC RANGE – The temperature range most conducive to maintenance of optimum digestion by thermophilic bacteria, generally accepted as between 120° and 135° F.

VOLATILE ACIDS (VA) – Fatty acids containing six or less carbon atoms, which are soluble in water and which can be steam-distilled at atmospheric pressure. Volatile acids are commonly reported as equivalent to acetic acid.

VOLATILE SOLIDS (VS) – The quantity of solids in water, wastewater, or other liquids, lost on ignition of the dry solids at 600° C.

ZOOGLEA – A jelly-like matrix developed by bacteria.

SECTION VII
ACKNOWLEDGEMENTS

The data received through personal communications with wastewater treatment plant superintendents and their staff, consulting engineers, start-up experts, the academic community, manufacturers and suppliers of wastewater treatment plant equipment, and EPA personnel is gratefully acknowledged.

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SECTION VIII
REFERENCES

1. Cassell, E. A. and Sawyer, C. N., "A Method for Starting High-Rate Digesters," *Sewage and Industrial Wastes*, Vol. 31, No. 2, p. 123 (February, 1959).

2. Caverly, D.S., "Start-up of New Wastewater Treatment Plants," *Journal WPCF*, Vol. 40, No. 4, p. 571 (April, 1968).

3. "Chlorine Manual," 4th edition, The Chlorine Institute, Inc. (December, 1972).

4. Dague, Richard R., "Application of Digestion Theory to Digester Control," *Journal WPCF*, Vol. 40, No. 12, p. 2021 (December, 1968).

5. Eckenfielder, A. W. and O'Conner, D. J., *Biological Waste Treatment*, Pergamon Press, 1961.

6. "Estimating Costs and Manpower Requirements for Conventional Wastewater Treatment Facilities," EPA, Contract No. 14-12-462, October, 1971.

7. Filbert, J. W., "Procedures and Problems of Digester Start-Up," *Journal WPCF*, Vol. 39, No. 3, p. 367 (March, 1967).

8. "Glossary of Water and Wastewater Control Engineering," APHA, ASCE, AWWA, WPCF, 1969.

9. Hatfield, W. D., "Operation of the Activated Sludge Process," *Journal WPCF*, Vol. 38, No. 6, p. 957 (June, 1966).

10. Hicks, C., "Digester Start-up at Cobourg, Ontario," *Sewage and Industrial Wastes*, Vol. 31, No. 1, p. 117 (January, 1959).

11. Ketcham, L., "Operator Ingenuity at the Tacoma, Washington, Sewage Treatment Plant," *Sewage and Industrial Wastes*, Vol. 30, No. 12, p. 1506 (December, 1958).

12. Kifer, L. D., "Start-up Problems at a Metropolitan District Plant," *Journal WPCF*, Vol. 40, No. 7, p. 1338 (July, 1968).

13. Kugelman, I. J. and McCarty, P. L., "Cation Toxicity in Stimulation in Anaerobic Waste Treatment," *Journal WPCF*, Vol. 37, No. 1, p. 97 (January, 1965).

14. Lohmeyer, G. T., "A Review of Sludge Digestion," *Journal WPCF*, Vol. 31, No. 2, p. 221 (February, 1959).

15. Lynam, B., McDonnell, G., and Krup, M., "Start-up and Operation of Two New High-Rate Digestion Systems," *Journal WPCF*, Vol. 39, No. 4, p. 518 (April, 1967).

16. McCarty, P. L. and McKinney, R. E., "Salt Toxicity in Anaerobic Digestion," *Journal WPCF*, Vol. 33, No. 4, p. 399 (April, 1961).

17. McCarty, P. L. and McKinney, R. E., "Volatile Acid Toxicity in Anaerobic Digestion," *Journal WPCF*, Vol. 33, No. 3, p. 223 (March, 1961).

18. McKinney, Ross E., *Microbiology for Sanitary Engineers*, McGraw-Hill Book Company, 1962.

19. *Manual of Instruction for Sewage Treatment Plant Operators*, New York State Department of Health.

20. *Manual of Wastewater Operations*, Texas Water Utilities Association, 1971.

21. Metcalf & Eddy, Inc., *Wastewater Engineering*, McGraw-Hill Book Company, Inc., 1972.

22. "Operation and Maintenance Manual, Wastewater Stabilization Lagoon and Lift Station," Culver Engineering, August 24, 1972.

23. "Operations of Wastewater Treatment Plants," Sacramento State College, Department of Civil Engineering.

24. "Plant Start-Up Procedure," Ontario Water Resources Commission, Division of Plant Operations, July, 1968.

25. Pohlard, F. G. and Ghosh, S., "Developments in Anaerobic Treatment Processes," Biotechnical and Bioengineering, Symposium No. 2, p. 85 (1971).

26. "Procedural Manual for Evaluating the Performance of Wastewater Treatment Plants," EPA, Contract No. 68-01-0107, *Standard Methods*, 13th edition, American Public Health Association, 1971.

27. *Recommended Standards for Sewage Works*, Great Lakes - Upper Mississippi River Board of State Sanitary Engineers, Health Education Service, Albany, New York.

28. "Safety Regulations," 3rd edition, Ontario Water Resources Commission, Division of Plant Operations, 1971.

29. Schlenz, H. E., "Important Considerations in Sludge Digestion. Part I - Practical Aspects," *Sewage Works Journal*, Vol. XIX, No. 1, p. 19 (January, 1947).

30. Schlenz, H. E., "Sludge Digestion - 1957 Operators Forum," *Sewage and Industrial Wastes*, Vol. 30, No. 4, p. 585 (April, 1958).

31. "Sewage Treatment Plant Manual," 2nd edition, OWRC, Division of Plant Operations, 1972.

32. Shafer, S. W., "Initial Digester Start-up at Alexandria, Virginia," *Sewage and Industrial Wastes*, Vol. 29 No. 10, p. 1190 (October, 1957).

33. *Standard Methods for the Examination of Water and Wastewater*, 13th edition, APHA, AWWA, WPCF, 1971.

34. "A Study of Sludge Handling and Disposal," U. S. Department of the Interior, Federal Water Pollution Control Administration, Publication No. WP-20-4, May, 1968.

35. Van Kleek, L. W., "Start-up of Separate Sludge Digesters," *Sewage and Industrial Wastes*, Vol. 30, No. 3, p. 312 (March, 1958).

36. West, A. W., PE, "Activated Sludge Process Operational Control," May, 1971.

37. West, A. W., PE, "Preliminary Report on Start-up of the Activated Sludge Process at the Lower Potomac Water Pollution Control Plant at Fairfax County, Virginia," February, 1971.

38. Wittenburg, John A., "Pilot Study to Determine Manpower Requirements for Conventional Sewage Treatment Plants," Manpower and Training Division, Federal Water Quality Administration, September, 1970.

39. *WPCF Manual of Practice No. 1*, "Safety in Wastewater Works," 1967.

40. *WPCF Manual of Practice No. 11*, "Operation of Wastewater Treatment Plants," 1966.

41. *WPCF Manual of Practice No. 16*, "Anaerobic Sludge Digestion," 1968.

42. White, George C., *Handbook of Chlorination*, Van Nostrand Reinhold Company, 1972.

SELECTED WATER RESOURCES ABSTRACTS Input Transaction Form	W

MANUAL OF CONSIDERATIONS AND TECHNIQUES FOR START-UP OF MUNICIPAL WASTEWATER TREATMENT FACILITIES

Rader, R. D.; Green, R. L., PE; Page, G. L., Jr., PE

WILEY & WILSON, INC.
ENGINEERS . ARCHITECTS . PLANNERS
LYNCHBURG, VIRGINIA

68-01-0341

This manual provides guidance for putting into initial operation a new municipal wastewater treatment plant, a new addition to an existing treatment plant, or a change in the mode of the treatment plant's operation so that the treatment plant or process will effectively treat the wastewater in compliance with the specific conditions and limitations established for each treatment facility.

The manual was developed and prepared with the aid and cooperation of wastewater treatment plant operators and superintendents, start-up experts, the academic community, manufacturers and suppliers of wastewater treatment plant equipment, and literature review of wastewater treatment plant operations and recognized start-up techniques.

Information is provided on preparing for actual treatment plant start-up. Preparations for start-up include: staffing the plant, developing standard operating procedures, dry- and wet-run testing of equipment, on-site operator training, safety, and establishing procedures when construction is continuing during start-up.

This manual describes start-up procedures for some of the more common pretreatment and primary treatment units; for the specific secondary treatment processes of activated sludge, trickling filters, stabilization ponds and aerated lagoons; and for the sludge handling units and the anaerobic digestion process. The start-up procedures for advanced wastewater treatment units and processes are not considered in this manual.

References for additional information and a glossary are also provided.

17a. Descriptors

*Administrative Decisions, *Laboratory Tests, *Sampling, *Testing, *Analysis, *Controls, Activated Sludge, Trickling Filter, Oxidation Lagoons, Anaerobic Digestion, Safety, Chlorination, Suspended Solids, Hydrogen Ion Concentration, Alkalinity, Biochemical Oxygen Demand, Chemical Oxygen Demand.

17b. Identifiers

*Start-Up, *Procedures, *Process, Seed Sludge, Primary Treatment, Pretreatment, Staffing, Standard Operating Procedures, Site Meetings, Inventory Inspection, Pretesting, Operator Training, Settleable Solids, Total Solids, Volatile Solids, Volatile Acids, Mixed Liquor Suspended Solids.

17c. COWRR Field & Group

10A

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